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ACOUSTIC MEASUREMENTS OF F-15 AIRCRAFT OPERATING IN HUSH HOUSE,--ETC(U)
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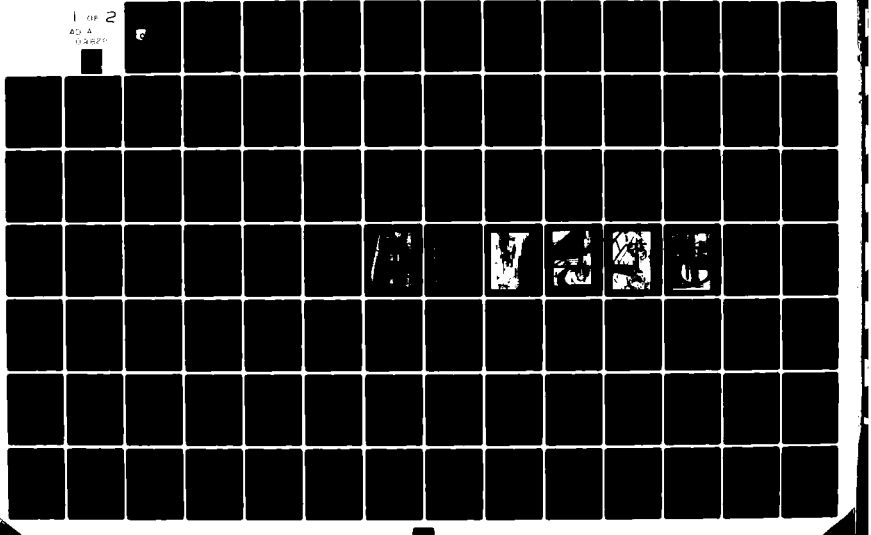

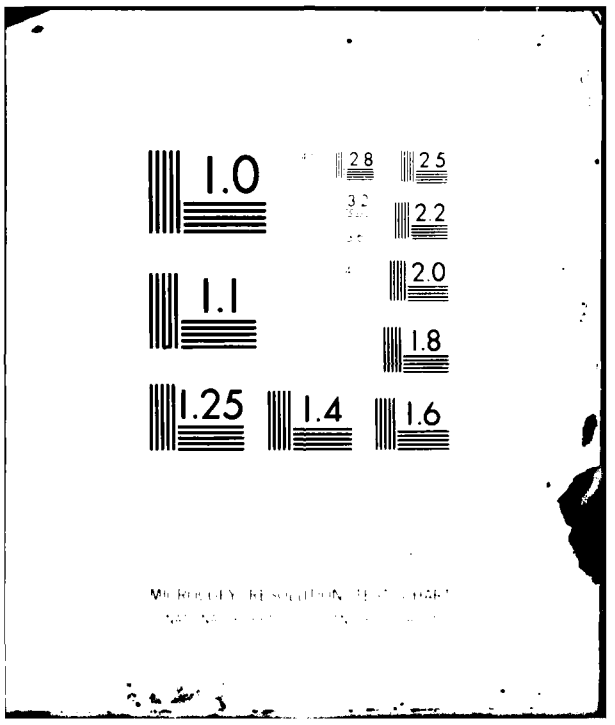
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ACOUSTIC MEASUREMENTS OF F-15 AIRCRAFT OPERATING IN HUSH HOUSE, NSN 4920-02-070-2721

V. R. MILLER
G. A. PLZAK
J. M. CHINN

SEPTEMBER 1981

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STRUCTURAL INTEGRITY BRANCH
STRUCTURES AND DYNAMICS DIVISION
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This technical report has been reviewed and is approved for publication.

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FOR THE COMMANDER:

DAVEY L. SMITH, Chief
Chief, Structural Integrity Branch

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Noise Suppression	Acoustics

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)* The purpose of this test program was to measure the acoustic environment in the hush house facility located at Kelly Air Force Base, Texas, during operation of the F-15 aircraft to ensure that aircraft structural acoustic design limits were not exceeded. The acoustic measurements showed that no potential sonic fatigue problems are anticipated with the F-15 aircraft structure during operation in the hush house. However, since these acoustic levels were increased over those measured during run-up on a concrete pad, it is recommended that F-15 equipment qualification levels be checked. The data indicated that the noise field within the hush

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house is diffuse and that the acoustical energy in the hangar area is radiated from the region between the engine exhaust and the hush house muffler front edge toward the forward part of the hangar.

FOREWORD

This effort was performed by the combined efforts of the Structural Integrity and Structural Vibrations Branches, Structures and Dynamics Division, Flight Dynamics Laboratory, Air Force Wright Aeronautical Laboratories, Wright-Patterson Air Force Base, Ohio. This effort was initiated under Project 7500, Program Element 921A, and performed in support of the first article hush house testing program at Kelly Air Force Base, Texas. This program was accomplished to assure contract compliance with respect to noise levels. The work was requested by the Deputy for F-15 Systems Program Office, Project and Test Division (Ref 1) and authorized by Project Order Number ASD-1-1210P. Mr S. Sawyer and Sgt J. Conroy (ASD/TAF) were the focal points for this activity. Mr G. E. Sherwood was the point of contact at Kelly Air Force Base.

The work was performed by Mr V. R. Miller of the Structural Integrity Branch and Mr G. A. Plzak and Ms J. M. Chinn of the Structural Vibrations Branch from May 1981 to September 1981. The authors wish to extend their appreciation to Messrs M. A. Hart and L. P. Vaughn who assisted with the data acquisition and reduction. Special acknowledgement is due Mmes J. Tope and M. Arnold for careful typing of the manuscript.

The manuscript was released by the authors in September 1981 as a technical memorandum. This technical memorandum has been reviewed and approved.

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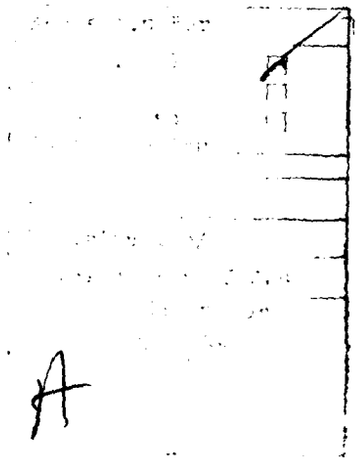

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I. INTRODUCTION

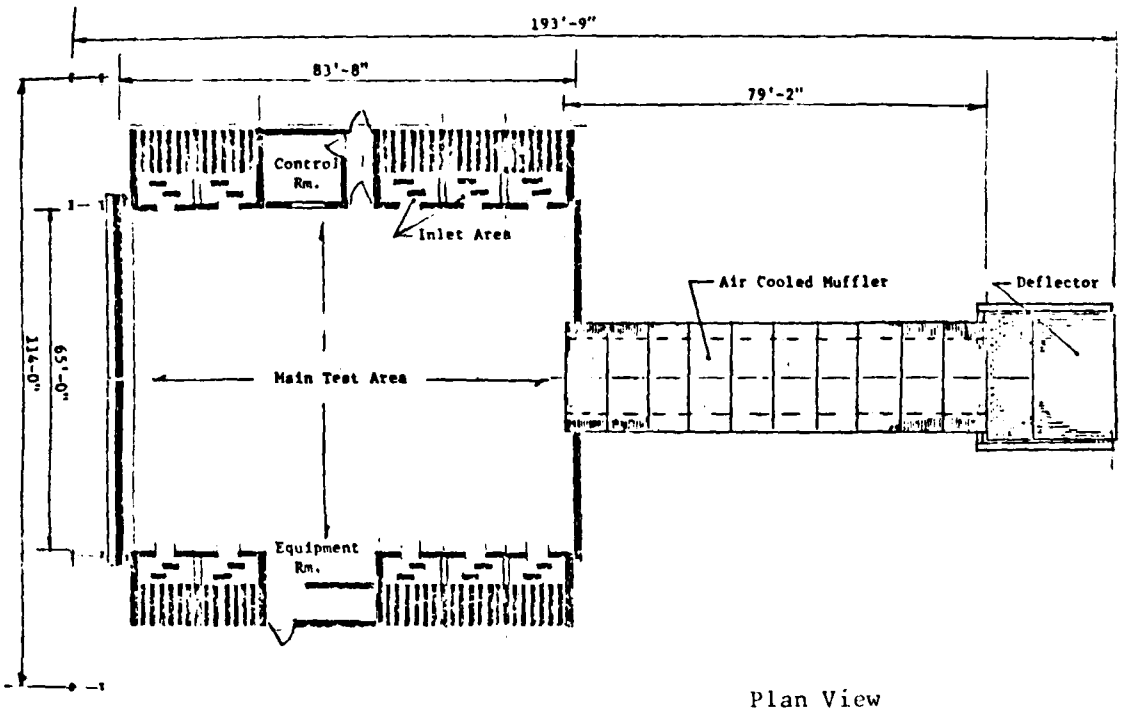
An Aero-System Engineering (ASE) hush house, NSN 4920-01-070-2721, was constructed at Kelly AFB, Texas. This hush house is an air cooled noise suppressor system (NSS) which completely encloses the aircraft for environmental control purposes during ground run-up. The NSS is compatible with all types of USAF fighter aircraft and is also capable of testing uninstalled engines. Enclosing an aircraft in such a manner will increase the sound pressure levels on the aircraft structure. Increasing these levels can decrease the fatigue life of the aircraft and compromise its structural integrity if structural acoustic design limits are exceeded. Qualification of the ASE hush house for the F-15 aircraft with respect to acoustics is essential. Recognizing these problems, the F-15 SPO requested (Ref 1) the Structures and Dynamics Division of the Flight Dynamics Laboratory to perform a test program to measure the acoustic environment with the F-15 operating in the ASE hush house. The purpose of this effort was to ensure that the acoustic environment within the hush house did not exceed structural design limits and to identify potential problems with the F-15 aircraft structure.

A brief description of the hush house is contained in Section II. Section III of this report describes the test, data acquisition, and data reduction procedures used during this program. A discussion of the results is included in Section IV. The conclusions determined from the program are given in Section V with recommendations shown in Section VI. Appendix A shows photographs taken at the test site to document transducer locations, aircraft orientation, etc. Data reduced from the measurements are included in Appendix B.

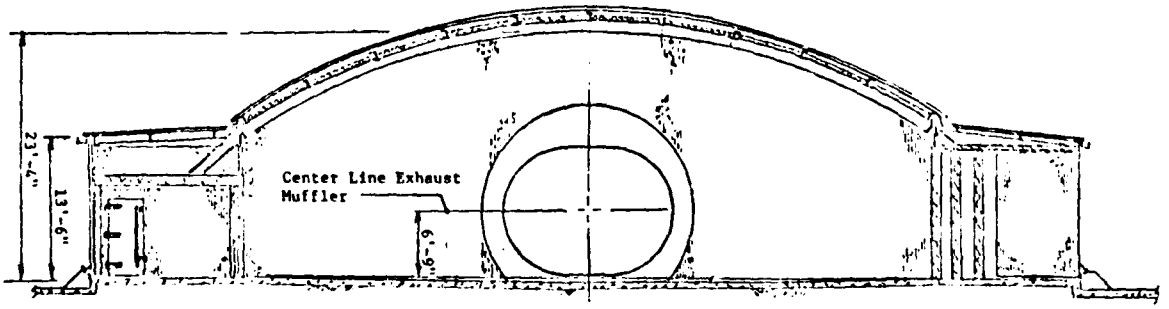
II. DESCRIPTION OF HUSH HOUSE

The hush house which was used during this program is shown in Figure 1. This structure consists of a sound-absorbent hangar with dimensions of approximately 84 by 65 feet (25.6 by 19.8 meters). The surfaces of the hangar were covered with approximately 10,500 square feet (975.5 m^2) of absorbing panels, 4 inches (10.2 cm) thick with a 20 gauge perforated face sheet (304 stainless steel), 16% open area and filled with 4.8 lb/ft^3 (76.9 Kg/m^3 fiberglas. The fiberglas was wrapped in a fiberglas cloth. The hangar fully encloses both entire aircraft and uninstalled engines during ground run-up. The hush house is suitable for testing aircraft of any size and configuration which are geometrically compatible. The aircraft are restrained by tail hooks, wheel chocks, and/or conventional steel cable tiedowns during engine run-up. This hush house is also air-cooled which eliminates the need for a water spray system in the muffler. Water spray has a deleterious effect on air quality and acoustic absorptive treatments.

The inlet area allows large air flows and low air velocity past the aircraft under test. The intake system has a bird screen. Downstream of the bird screen are sound-absorbent baffles arranged as a labyrinth. The aircraft jet exhausts into a muffler. Large volumes of air are pumped through the intake system, over the aircraft, and into the muffler to cool the engine exhaust. The muffler is made in sections, each of which consists of several chambers. The inner shell is made of perforated and corrugated 321 stainless steel with 4.5 lb/ft^3 (72.1 Kg/m^2) of Basalt wool fill, 4 inches (10.2 cm) thick around the shell. The exhaust gases leaving the muffler are directed vertically by a deflector.



Plan View



Front Elevation

FIGURE 1 Layout of Hush House

III. TEST, DATA ACQUISITION, AND DATA REDUCTION PROCEDURES

The measurements were conducted at Kelly Air Force Base, Texas from 1 June to 4 June 1981, with the F-15 aircraft (S/N 76-089) operating in the hangar area of the hush house. The F-15 is an air superiority fighter aircraft powered by two F100-PW-100 turbofan engines (left S/N 681530, right S/N 681489) which are the major source of ground run-up noise.

The different test runs performed are identified in Table 1. The tests were made with the hangar doors open and closed. All data were recorded once the engines had stabilized except for the snap run where the throttle is abruptly changed from idle to full A/B. Typical engine data recorded are also shown in Table 1. Table 2 lists the surface meteorological conditions during data acquisition.

The basic transducers used during the test program were located as shown in Figures 2 and 3 and Table 3. The test instrumentation consisted of 25 Gulton Industries Model MVA2100 5/8 inch (1.6 cm) microphones. The microphones were surface-mounted on the aircraft structure and located close to the stiffened panels in order to minimize vibration input to the microphones (preclude measuring dynamic response of the panel).

The test procedures which were used were as follows:

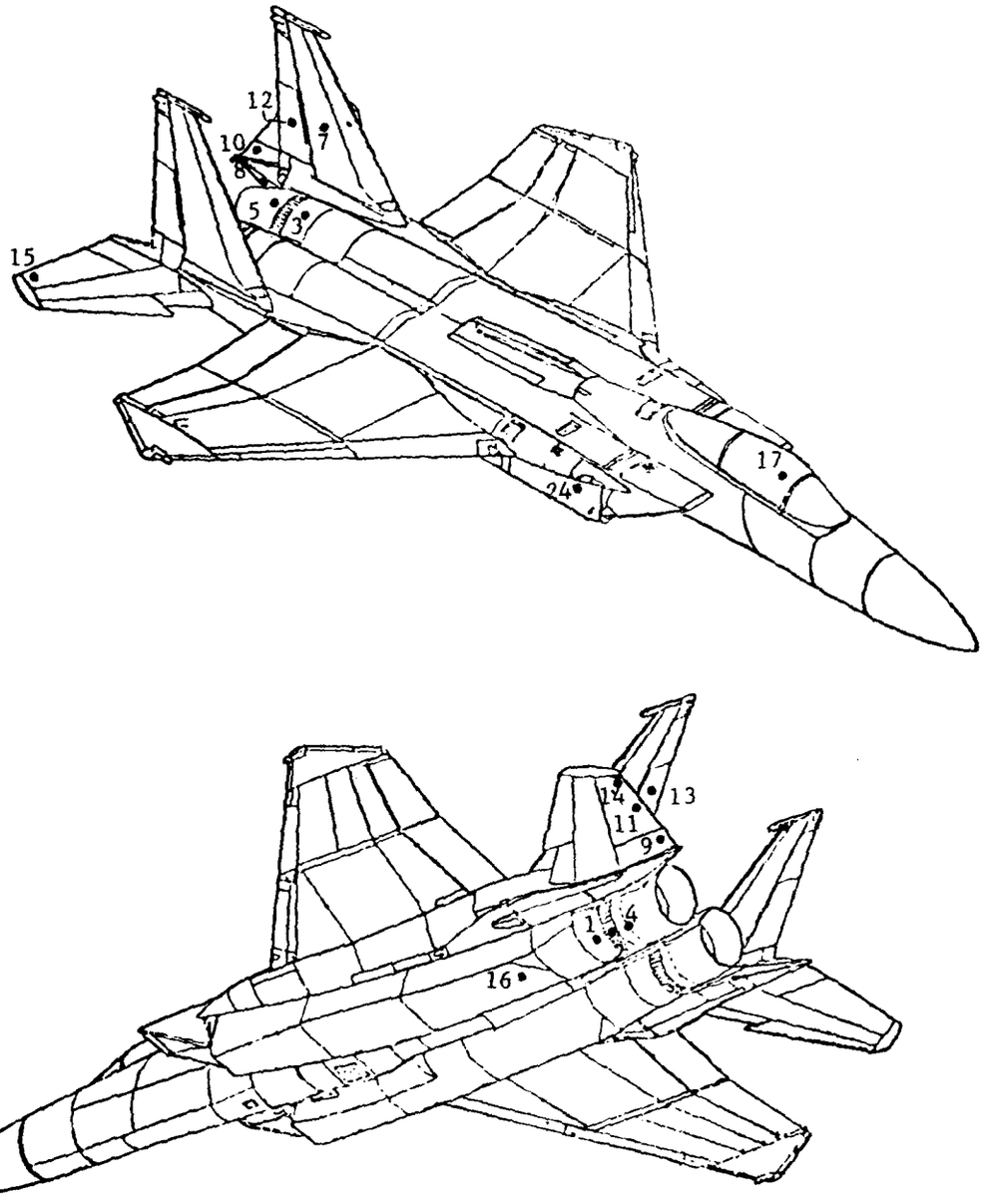
1. Install the F-15 in the hush house hangar area and locate microphones.
2. Calibrate all data recording instrumentation.
3. Record ambients prior to test runs.
4. Operate engines for 20-25 seconds at each of the conditions shown in Table 1.
5. Edit and review data tapes for quality.
6. Repeat any test condition shown to be deficient from step (5).

TABLE 1. SUMMARY OF TEST RUNS AND COCKPIT READOUTS OF F-15 AIRCRAFT

Date and Approximate Time	Engine Power Settings		Fan Turbine Inlet Temperature (°F)/(°C)	Fuel Flow (lbm/hr)/(kg/hr)	Hush House Doors	Record Number
	Left (Port)	Right (Starboard)				
2 June 81 1500 hrs.	Ambient	Ambient	85/30	0/0	Closed	1
	80%	Idle	1274/690	4100/1861	Closed	2
	85%	Idle	1292/700	4200/1907	Closed	3
	Idle	Military	1679/915	11,000/4994	Closed	4
	77%	Max. A/B	1679/915	39,000/17,706	Closed	5
3 June 81 1000 hrs.	Ambient	Ambient	32/28	0/0	Open	6
	Ambient	Ambient	82/28	0/0	Open	7
	Idle	Military	1670/910	7400/3360	Open	8
	Military	Idle	1670/910	7400/3360	Open	9
	Max. A/B	Idle	1670/910	38,000/17,252	Open	10
	Snap	Idle	---	----	Open	11
	Military	73%	---	----	Open	12
3 June 81 1600 hrs.	Military	Idle	---	----	Closed	13
	Max. A/B	Idle	---	----	Closed	14

TABLE 2. METEOROLOGY

Date and Approximate Time	Temperature (°F)/(°C)	Barometric Pressure (psi)/(in. Hg.)	Relative Humidity (%)	Wind	
				Speed (Knots)/(km/hr)	Direction (Degrees)
2 June 81 1500 hrs.	85/29	14.30/29.105	75	8/14.8	210
3 June 81 1000 hrs.	82/28	14.29/29.100	71	10/18.5	160
3 June 81 1600 hrs.	89/32	14.27/29.045	57	10/18.5	150



NOTE: Microphones 1 through 14 and 16 were located on starboard side of aircraft during tests.

FIGURE 2 Location of Microphones 1-17 and 24 on F-15 Aircraft

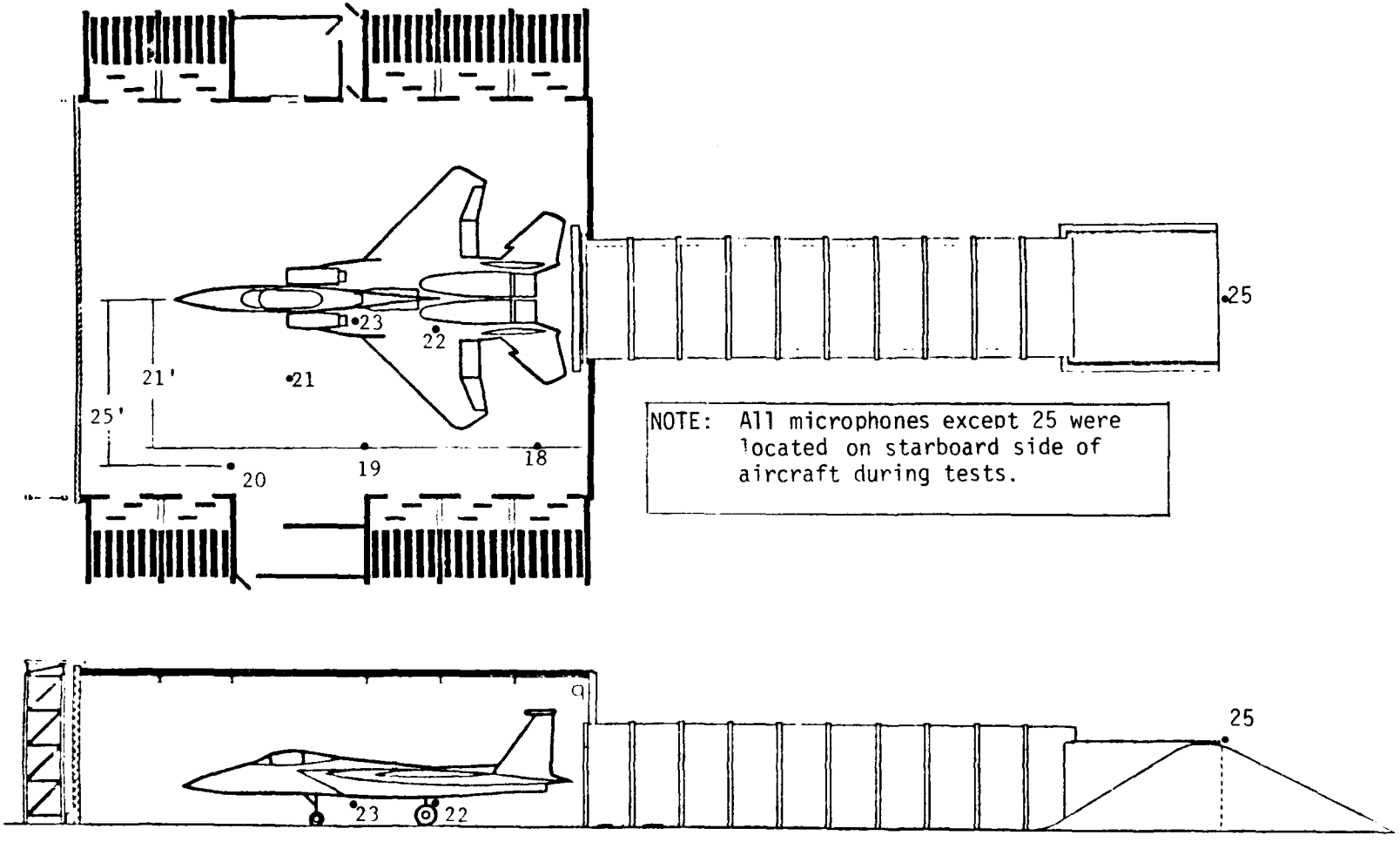


FIGURE 3 Location of Microphones 18-23 Around F-15 Aircraft and Microphone 25 at Top of Deflector.

TABLE 3. INSTRUMENTATION LOCATIONS

Microphone	Location
1	Right Aft Engine Fairing, Lower Side
2	Right Engine Static Nozzle Structure, Lower Side
3	Right Aft Engine Fairing, Upper Side
4	Right Engine Nozzle Flap Structure, Lower Side
5	Right Engine Nozzle Flap Structure, Upper Side
6	Right Aft Sidewall Fairing, Fwd.
7	Inboard Side, Right Vertical Stabilator
8	Right Aft Sidewall Fairing, Aft.
9	Lower Surface Right Horizontal Stabilizer, Inboard, Aft
10	Upper Surface Right Horizontal Stabilizer, Inboard, Aft
11	Lower Surface Right Horizontal Stabilizer, Outboard, Aft
12	Inboard Side, Right Rudder
13	Outboard Side, Right Rudder
14	Lower Surface Right Horizontal Stabilizer, Outboard Tip
15	Upper Surface Right Horizontal Stabilizer, Outboard Tip
16	Right Engine Compartment, Behind Access Door
17	Cockpit-Closed
18	Near-field Maintenance Position
19	Near-field Maintenance Position
20	Near-field Maintenance Position
21	Near-field Maintenance Position
22	Near-field Maintenance Position
23	Near-field Maintenance Position
24	Panel on Sidewall of Inlet Duct
25	Top of Hush House Deflector

The Flight Dynamics Laboratory's mobile data acquisition van contained the signal conditioning electronics and tape transports used for this test program. A block diagram of the instrumentation is shown in Figure 4. Landlines carry the data signal from each microphone to the van. The signal conditioning equipment is capable of producing either attenuation or amplification in 10 dB steps over the range -10 dB to +60 dB. The tape recorders used were Honeywell Model 96 frequency modulation (FM) systems. A time code was produced by a Systron-Donner 8350 time code generator and recorded on one channel of both magnetic tape recorder/reproducers.

The microphones were calibrated by means of a Bruel and Kjaer Type 4220 pistonphone. The magnetic tapes which recorded the data from the tests were played back in the laboratory at Wright-Patterson AFB on the Honeywell 96 record-reproduce system. All Analyses were obtained using a General Radio 1921/1926 one-third octave band analyzer interfaced with an ITI 4900 A/D system. All analyses were processed by a Raytheon 704 computer interfaced with a Gould 4800 high speed plotter. Figure 5 shows a block diagram of the overall data reduction process.

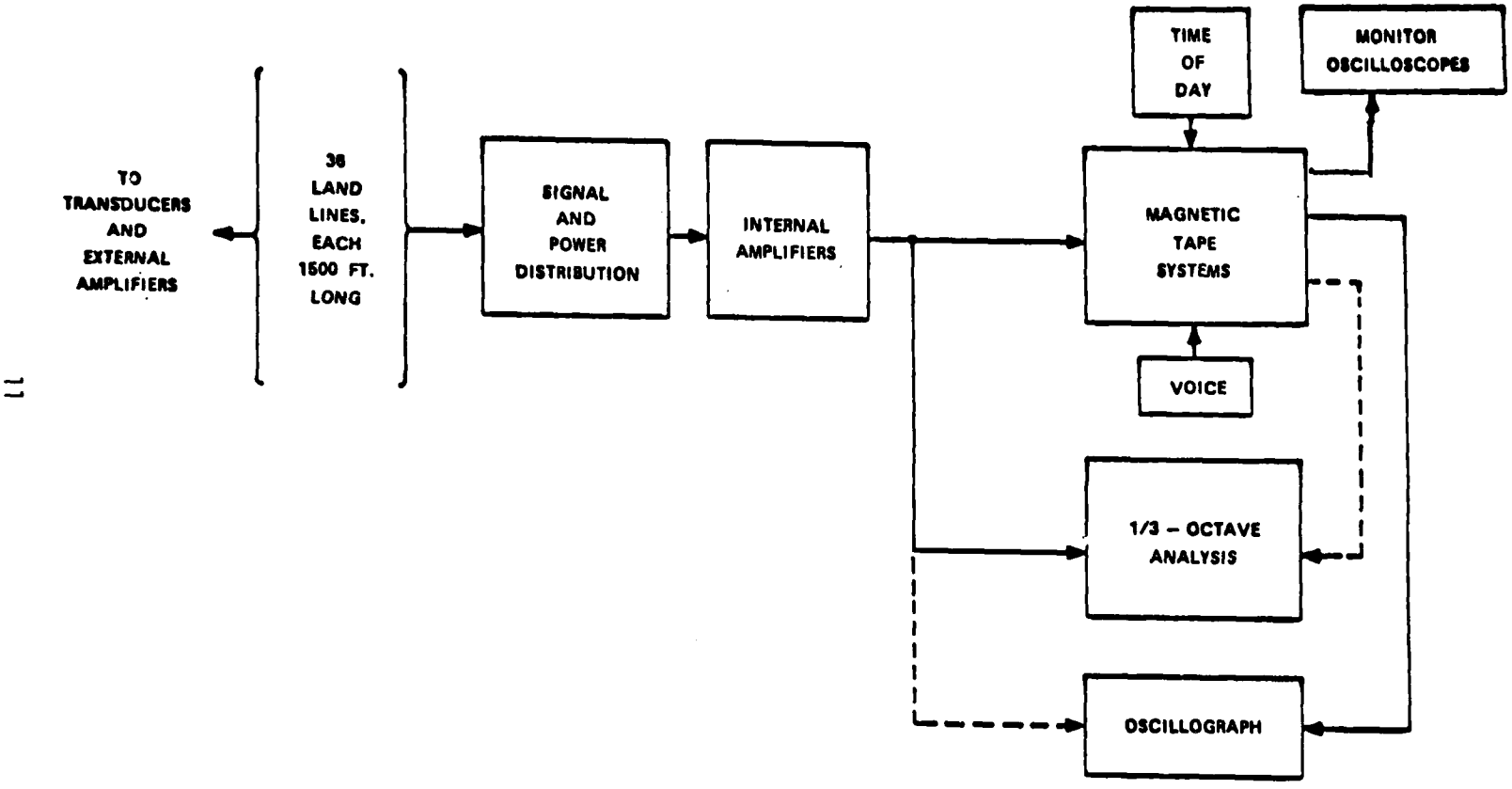


FIGURE 4 Schematic of Data Acquisition System

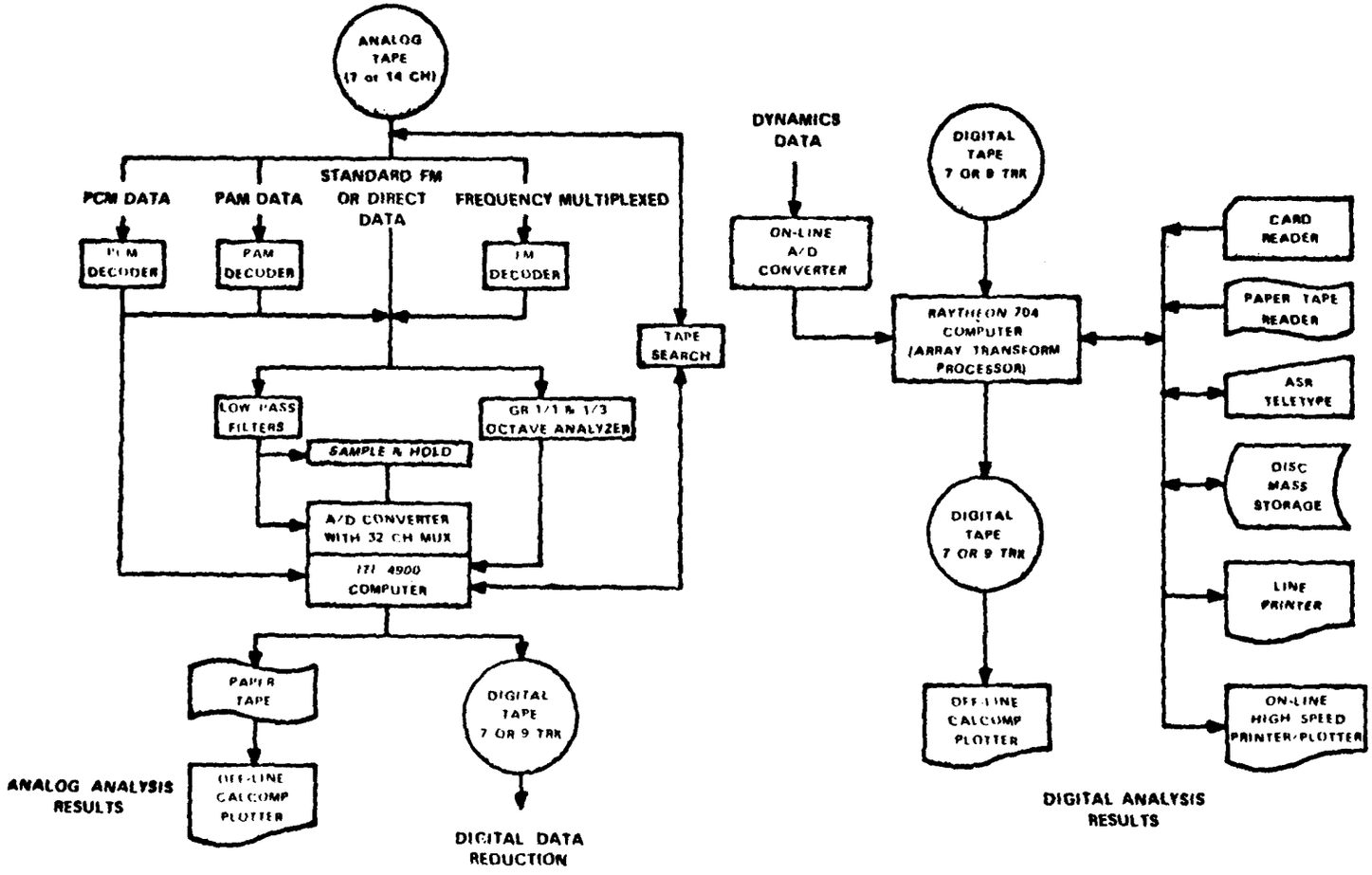


FIGURE 5 Data Reduction Process Diagram

IV. DISCUSSION OF RESULTS

A. Sound Pressure Level Near Aircraft Skin

Seventeen different microphones (Figure 2, microphones 1 through 16 and 24) were located in close proximity to the aircraft skin to obtain an indication of the maximum noise exposure. The microphones were positioned two inches (5.1 cm) from the surface in question with the microphone diaphragms pointed toward the surface. The octave band sound pressure levels which should not be exceeded for microphones 1 through 13 are reported in USAF Exhibit ENCM-75-2 (Ref 2) and shown on Table 4. Levels much greater than those shown in this table could cause sonic fatigue problems with the aircraft structure. Octave band sound pressure levels for microphones 1-13 are plotted in Figure 6 along with the allowable levels from Table 4. This figure shows that the measured sound pressure levels with the right engine at maximum afterburner (Record number 5, see Table 1) are, for the most part, well below the maximum allowable noise levels. Consequently, no sonic fatigue problems are anticipated with the F-15 aircraft structure during operation in the hush house.

Figure 7 shows a comparison of octave band sound pressure levels (SPL) for microphones 5, 6, and 13 with the right engine at maximum afterburner (A/B) and left engine at 77% (Record number 5) with data measured under similar conditions and microphone locations in existing F-15 water-cooled noise suppressors (Ref 3 and 4). The measured sound pressure levels are 2 to 11 dB less for frequencies below 1000 hertz. This is partly due to the larger size of the interior space in the hush house, where the reflecting interior walls are farther from the microphone

TABLE 4 **MAXIMUM ALLOWABLE NOISE LEVELS**
F-15 AFT STRUCTURE

STRUCTURE LOCATION	OCT. BAND CTR. FREQ. 63	125	250	500	1000	2000	4000	8000 HZ.
AIRCRAFT NOZZLE FAIRINGS	148	151	153	151	149	145	142	141 DB
ENGINE NOZZLES	134	141	145	148	150	152	158	155
STABILATOR BOOM FAIRINGS	153	153	153	155	156	155	153	150
HORIZONTAL STAB., VERTICAL TAIL, RUDDER	151	151	151	153	154	153	151	148

Structure Location

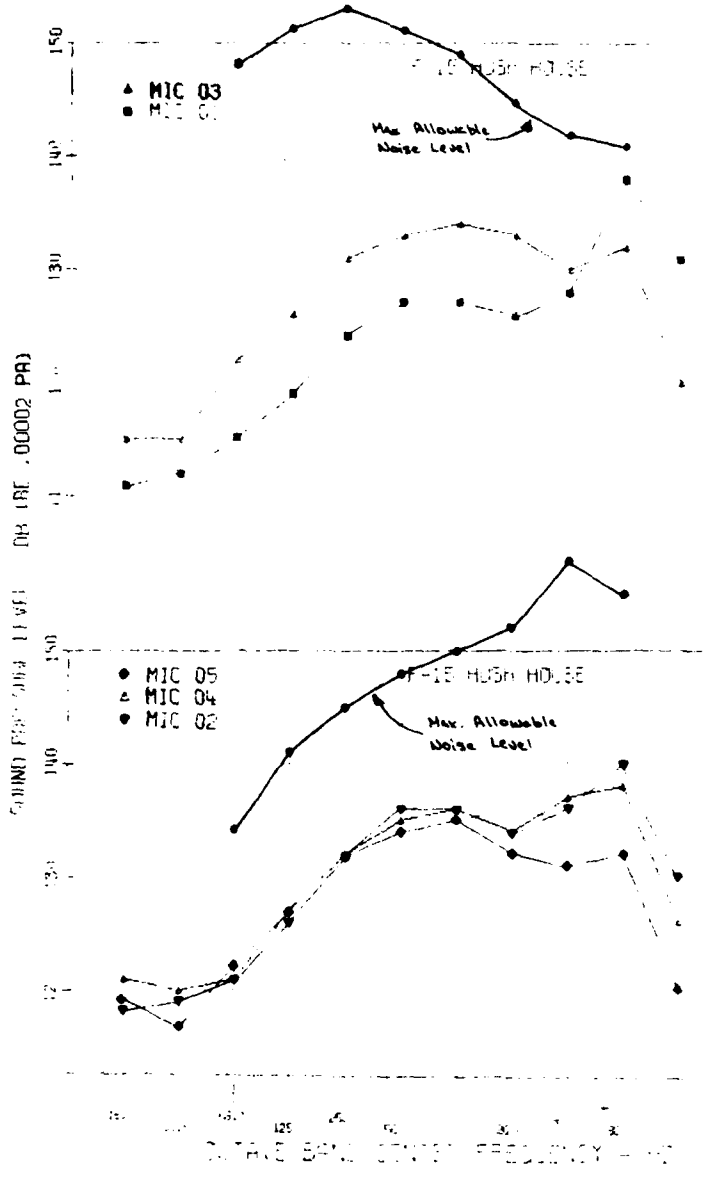
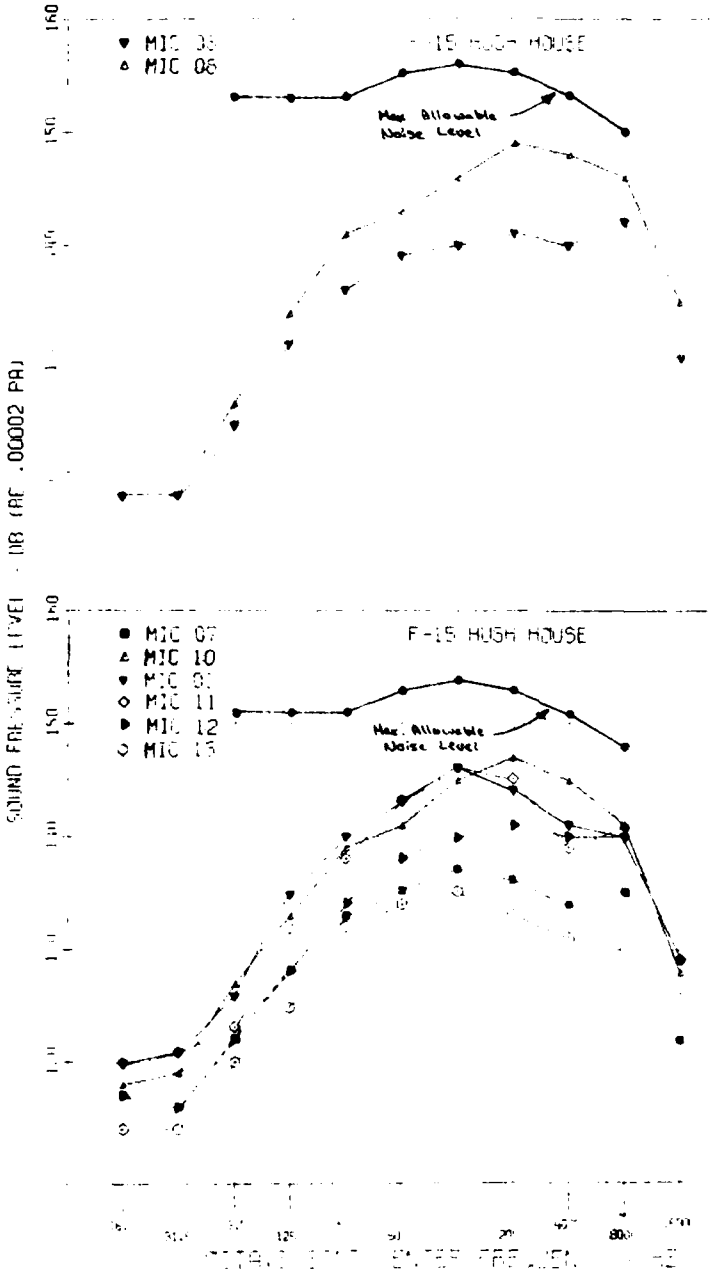


FIGURE 6 Comparison of Sound Pressure Levels Measured During Maximum Afterburner (Record Number 5) and Maximum Allowable Noise Levels on F-15 Aircraft Structure

Structure Location



Stabilator Boom Fairings

Horizontal Stab., Vertical Tail, Rudder

FIGURE 6 (cont'd) Comparison of Sound Pressure Levels Measured During Maximum Afterburner (Record Number 5) and Maximum Allowable Noise Levels on F-15 Aircraft Structure

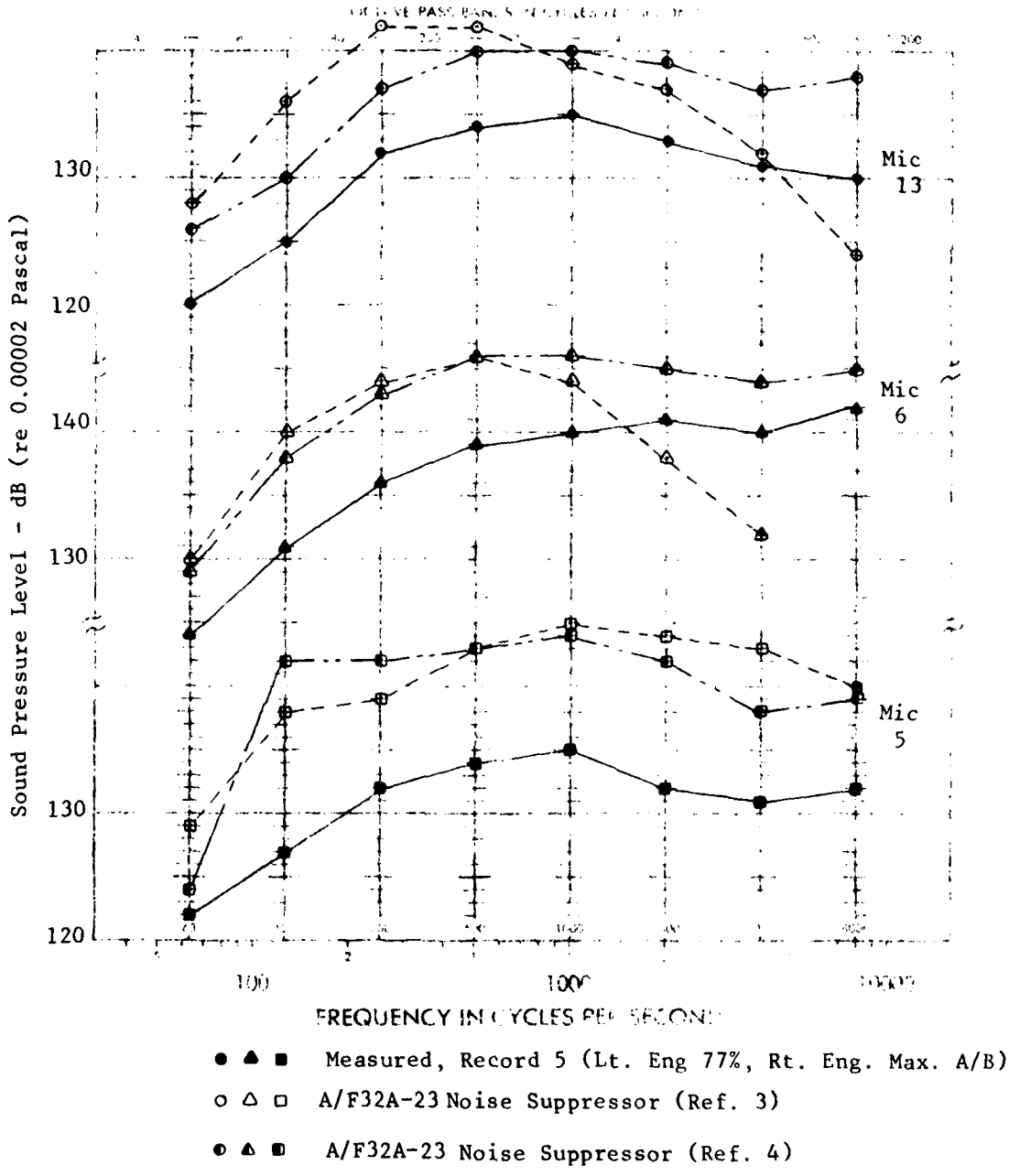


FIGURE 7 Comparison of Octave Band Sound Pressure Levels Near F-15 Aircraft Skin Measured in Hush House and A/F32A-23 Noise Suppressor

than in the water-cooled suppressors. This is important from a sonic fatigue and structural response standpoint. Another interesting comparison results when comparing the measured data with data obtained during aircraft run-up on a concrete pad (Ref 5 and 6). Figure 8 shows this comparison for four microphones on the aircraft surface (6, 16, 22, and 23). Note that the sound pressure levels are increased on the aircraft during operation in the hush house from 1 to 5 dB between 250 and 4000 hertz. This increase is much less than the 6 to 15 dB increases reported in another hush house (Ref 7). An increase in the acoustic environment will produce a corresponding dynamic stress increase on the aircraft structure (Ref 8). If the SPL increase is assumed to be the same in a narrowband as the octave band and is 3 dB (midway between the 1 to 5 dB mentioned above), the stress increase will be 1.4. This stress increase for a typical aluminum stiffened panel will decrease the life of the structure. These load increases should be specified in the structural design criteria for aircraft which are subjected to hush house operation.

Increasing the sound pressure levels can also cause fatigue problems with equipment and avionics. Equipment on-board the F-15 aircraft may not be qualified to the sound pressure levels reached during hush house operation and may be sensitive to acoustic excitation. The equipment could respond in such a manner that would modify or possibly disrupt its mode of operation or even result in mechanical failure. F-15 equipment qualification levels should be checked against the increases in the sound pressure levels shown here to determine if the equipment has been qualified for this type of operation.

Figure 8 also shows that the measured hush house sound pressure levels below 250 hertz are less than those measured during ground run-up on a

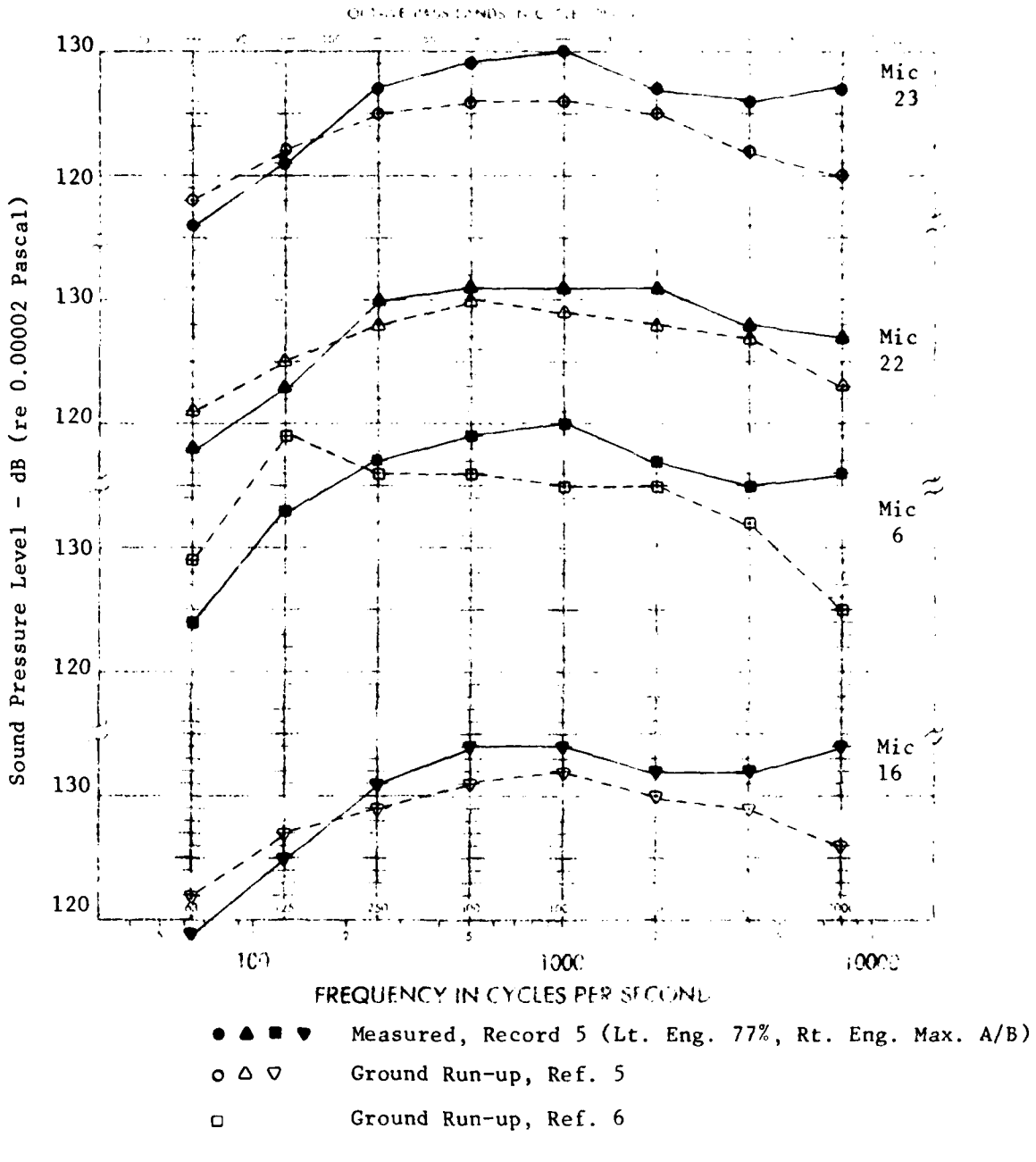


FIGURE 8 Comparison of Octave Band Sound Pressure Levels Measured in Hush House and Ground Run-up.

concrete pad. This reduction in SPL is attributed to the hush house exhaust muffler. The low frequency portion of the spectrum is generated far downstream of the nozzle inside the exhaust muffler.

B. Sound Pressure Level at Top of Hush House Deflector and Far Field

The noise field present at the end of the hush house muffler was evaluated using microphone 25 which was located at the jet exit deflector ramp, as shown in Figure 3. This microphone was located as close to the deflector as possible so that the measured levels were not affected by extraneous noise sources. Figure 9 presents narrowband (0.5 Hz) spectra for microphone 25 with the left engine operating at maximum afterburner and then military power and the right engine at idle and the hush house hangar doors open and closed. The muffler is attenuating all but the very low frequencies as seen by the spectrum shape. The sound pressure levels with the hangar doors closed are less than levels measured with the hangar doors open. This difference is as large as 5 dB when the left engine is operating at military power.

The data from microphone 25 can be used to extrapolate the sound pressure levels to positions 250 feet away from the deflector. Converting the maximum afterburner sound pressure levels of Figure 9 to 63 and 125 hertz octave band sound pressure levels and extrapolating to 250 feet, the sound pressure levels are 88 and 85 dB, respectively. These sound pressure levels do not exceed the values of 94 and 91 dB specified for a grade II type of noise suppressor (Ref 9).

C. Sound Pressure Levels at Maintenance Positions, Cockpit, Control Room

Several different locations were measured in and around the aircraft to determine the noise environment for the personnel stationed in these areas

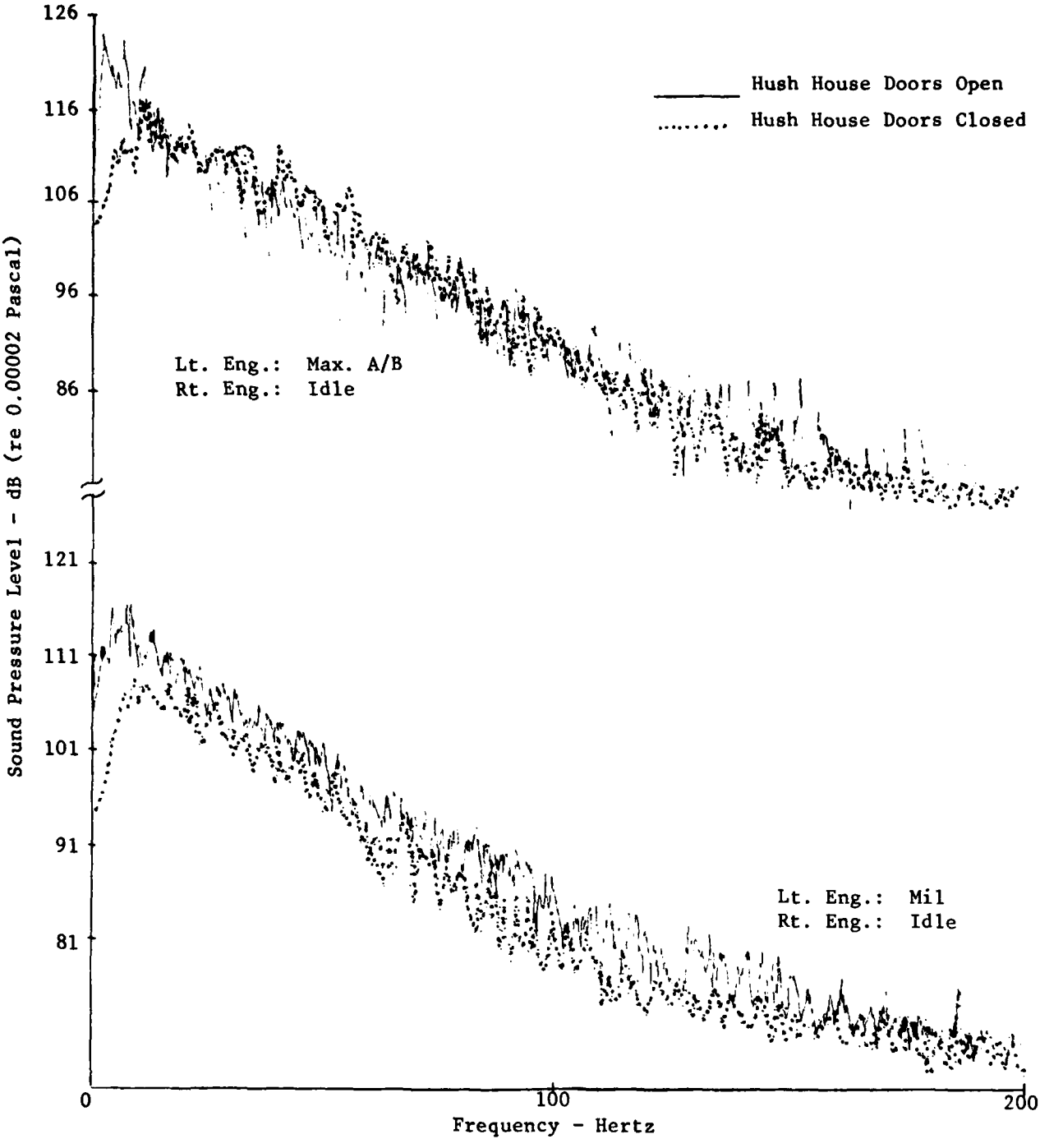


FIGURE 9 Narrowband (0.5 Hz) Spectra with F-15 A/C Operating in Hush House for Microphone 25 Located at Top of Deflector

during aircraft tiedown and run-up. These microphones (14, 17, 18, 19, 20, 21, 22 and 23) were positioned at approximately the ear level of the personnel. Table 5 summarizes the data at these microphone locations in terms of A-weighted overall sound pressure level to assess the effects of noise on personnel and their performance. These data are with the left engine at 77% and the right engine at maximum afterburner (record number 5). Four entries are made in the table. The first entry is for no hearing protection. The other entries are for ear protection commonly used in ground crew environments for which limiting exposure times were provided (Ref 10). Air Force Regulation 161-35 (Ref 11) sets forth the exposure limitations for the protection of hearing in terms of the A-weighted overall sound level and length of time exposed daily. Table 5 shows that some form of ear protection should be required at all locations. The amount of protection ultimately needed will be a function of the location and exposure time. The ground communication unit should probably be adequate for most situations since it is highly unlikely that personnel will be positioned close to the horizontal stabilator area during maximum afterburner operation (mic 14).

Data were also recorded in the hush house control room at the operator's station during military and maximum afterburner operation with the hangar doors closed (record numbers 13 and 14). These data were acquired with a portable Rion hand held sound level meter. A-weighted overall sound pressure levels for military and maximum A/B were 70 dBA and 74 dBA, respectively. These levels varied by ± 2 dBA during acquisition. The acoustical requirement specified in Reference 2 for the operator's posi-

TABLE 5 MEASURE OF HUMAN NOISE EXPOSURE DURING F-15 AIRCRAFT ENGINE OPERATION AT MAXIMUM AFTERBURNER

Type of Protection (from Ref. 10)	A-Weighted Overall Sound Level, dBA*/Maximum Permissible Time, Minutes							
	Mic 14	Mic 17	Mic 18	Mic 19	Mic 20	Mic 21	Mic 22	Mic 23
No Protection	148/P	110/5	141/P	134/P	131/P	132/P	137/P	135/P
Minimum QPL Ear Muffs	123/P	85/404	116/P	109/6	106/11	107/9	112/3.8	110/5
H-133 Ground Communication Unit	119/P	81/807	112/3.8	105/13	102/21	103/18	108/8	106/11
American Optical 1700 Ear Muffs Plus V-51R Ear Plugs	107/9	69/960	100/30	93/101	90/170	91/143	96/60	94/85

* Based on calculated SPL spectrum under protective device.

P Additional ear protection required.

TABLE 5 MEASURE OF HUMAN NOISE EXPOSURE DURING F-15 AIRCRAFT ENGINE OPERATION AT MAXIMUM AFTERBURNER

Type of Protection (from Ref. 10)	A-Weighted Overall Sound Level, dBA*/Maximum Permissible Time, Minutes							
	Mic 14	Mic 17	Mic 18	Mic 19	Mic 20	Mic 21	Mic 22	Mic 23
No Protection	148/P	110/5	141/P	134/P	131/P	132/P	137/P	135/P
Minimum QPL Ear Muffs	123/P	85/404	116/P	109/6	106/11	107/9	112/3.8	110/5
H-133 Ground Communication Unit	119/P	81/807	112/3.8	105/13	102/21	103/18	108/8	106/11
American Optical 1700 Ear Muffs Plus V-51R Ear Plugs	107/9	69/960	100/30	93/101	90/170	91/143	96/60	94/85

* Based on calculated SPL spectrum under protective device.

P Additional ear protection required.

tion inside the control room is 72 dBA. No problems are anticipated with hearing damage for personnel located in the control room based on these levels.

D. Near Field

The noise environment at positions to the side of the aircraft (microphones 18-21, see Figure 3) are summarized in Figure 10. These locations are major maintenance positions where personnel often are stationed during normal trim run-up operations. This figure includes the measured data as well as similar locations from ground run-up in the open (Ref 5). Note that the measured hush house sound pressure levels are greater in the higher frequencies than in the open and less in the lower frequencies. This same trend also applied to the SPL measured near the aircraft skin (see Figure 8).

Another way to compare the noise environment in the hush house to that existing when the aircraft is operated in the open is to compute the average SPL from the data for microphones 18, 19, and 20 on Figure 10. This average SPL represents an average of the noise and is defined as:

$$SPL_{Ave} = 20 \log \frac{\sqrt{\frac{P_{18}^2 + P_{19}^2 + P_{20}^2}{n}}}{.00002}, \quad \text{dB re 0.00002 Pascal}$$

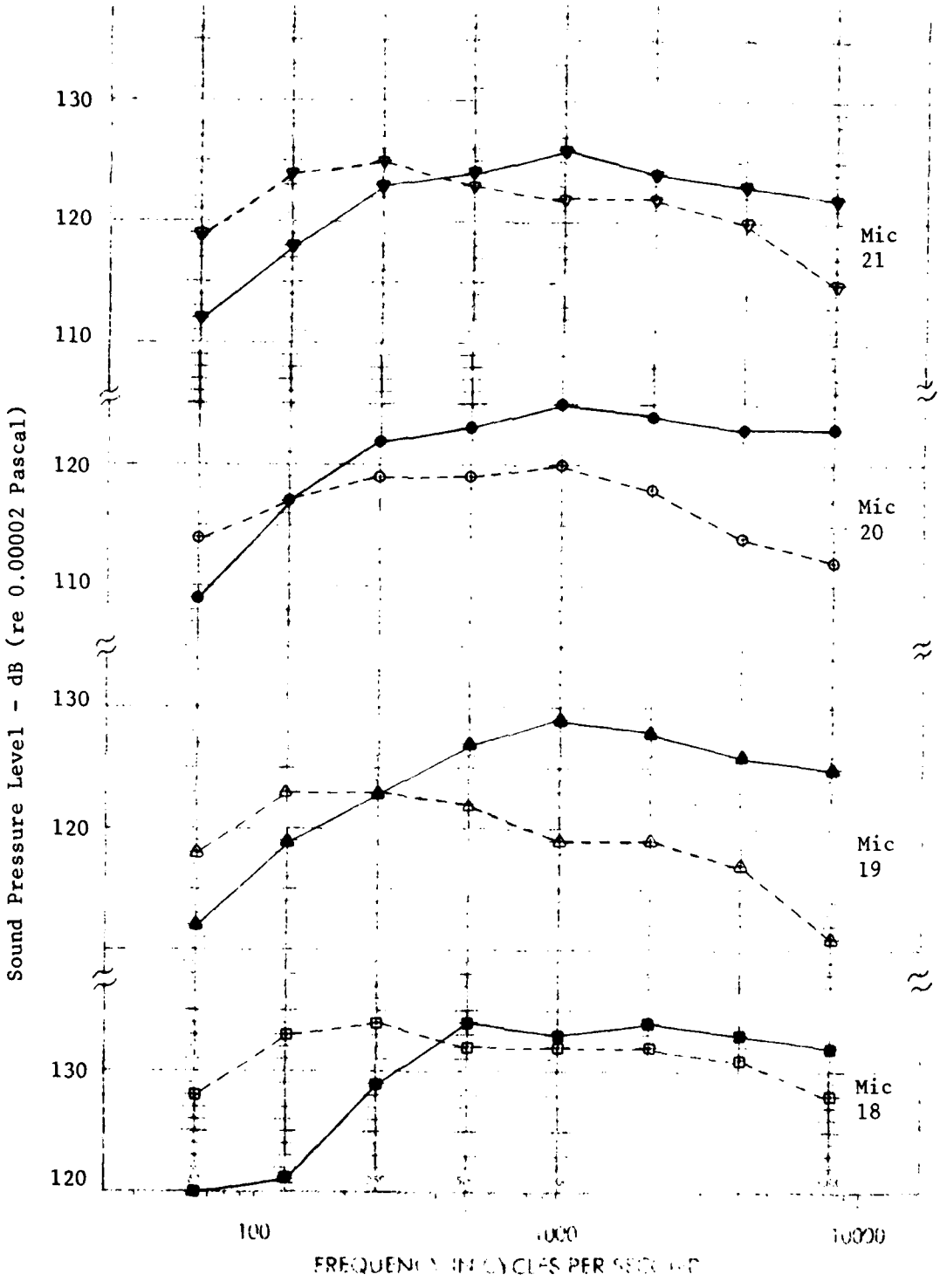


FIGURE 10 Comparison of Octave Band Sound Pressure Levels Measured in Hush House and Ground Run-up

Where P_{18}, P_{19}, P_{20} are the RMS sound pressure in Pascal

n = number of measurement positions = 3 for present case

The average SPLs inside the hush house, together with their ranges, are given in Figure 11, where they may be compared directly with the average SPL measured in the open. The range of SPL in the hush house data is relatively small. The average SPL is 4-9 dB less than ground run-up in the open below 250 hertz, but it is 2-5 dB greater above 250 hertz.

An investigation was made to determine the noise field within the hangar area when the aircraft operated one engine at maximum afterburner and the other at approximately idle. The result is given in Figure 12 which presents a series of contours of equal SPL in 2 dB steps for one-half of the hangar area for the overall level and the octave bands from 63 to 8000 hertz. This figure shows that the sound energy in the hangar area is radiated between the engine exhaust plane and the entrance to exhaust muffler (augmentor) toward the forward part of the hangar area. Energy is reflected back from the muffler to the hangar area together with that generated in the gap between the aircraft engine exhaust and the muffler opening. The SPL increase which was measured in the higher frequencies when moving the aircraft from the open to the hangar area is controlled by this separation distance between exhaust nozzle and muffler. The higher frequency energy is radiated directly into the hangar area rather than into the exhaust muffler. This suggests that the sound pressure levels in the hangar area can be lowered by proper positioning of the engine exhaust relative to the muffler entrance. For the present case the gap begween engine exhaust nozzle and the muffler is approximately 9 feet. If this distance could be shortened, an effective reduction in the percentage of acoustic energy radiated into

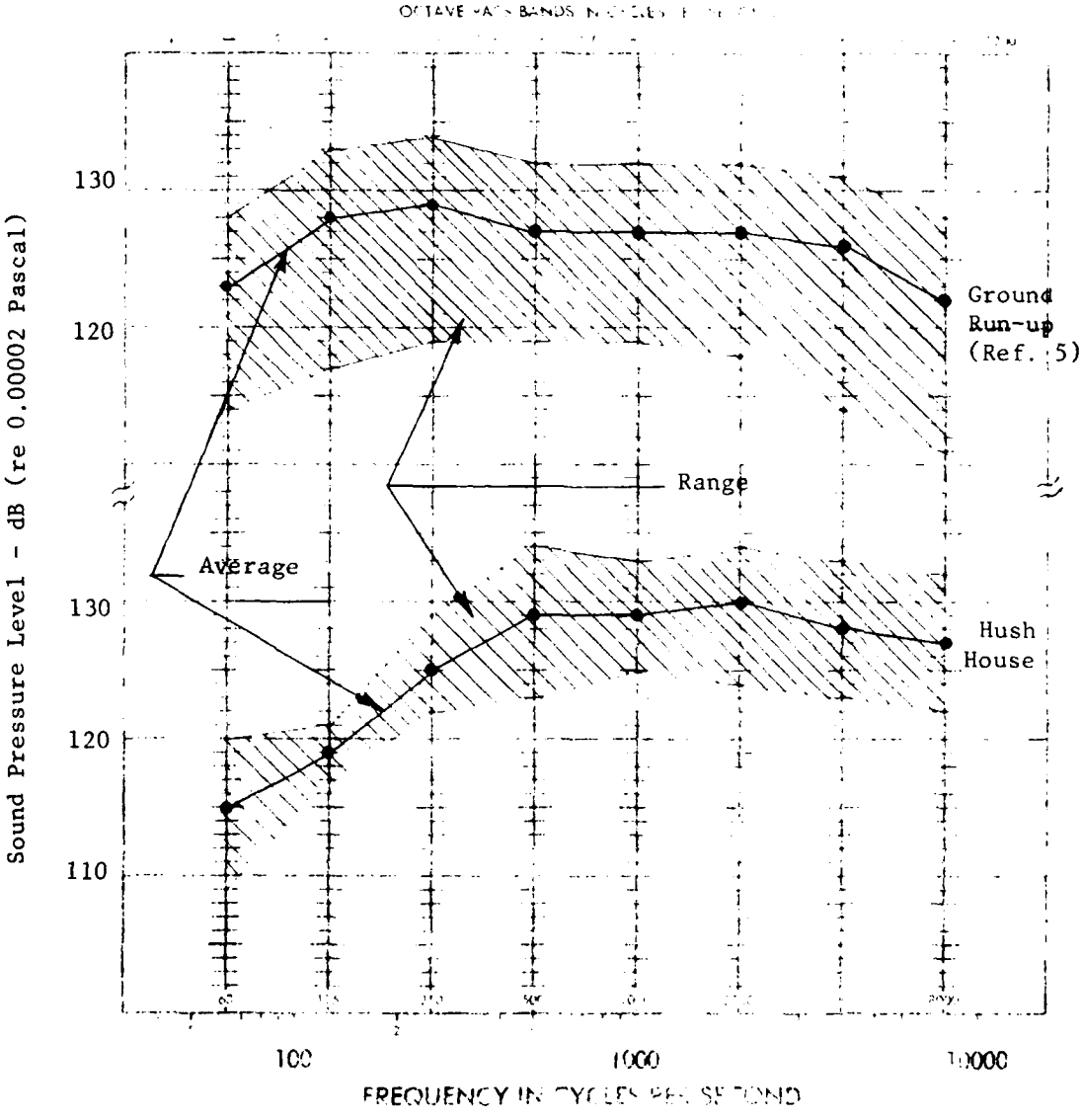


FIGURE 11 Average SPL and Range for **Field** Positions in Hush House and Ground Run-up in Open.

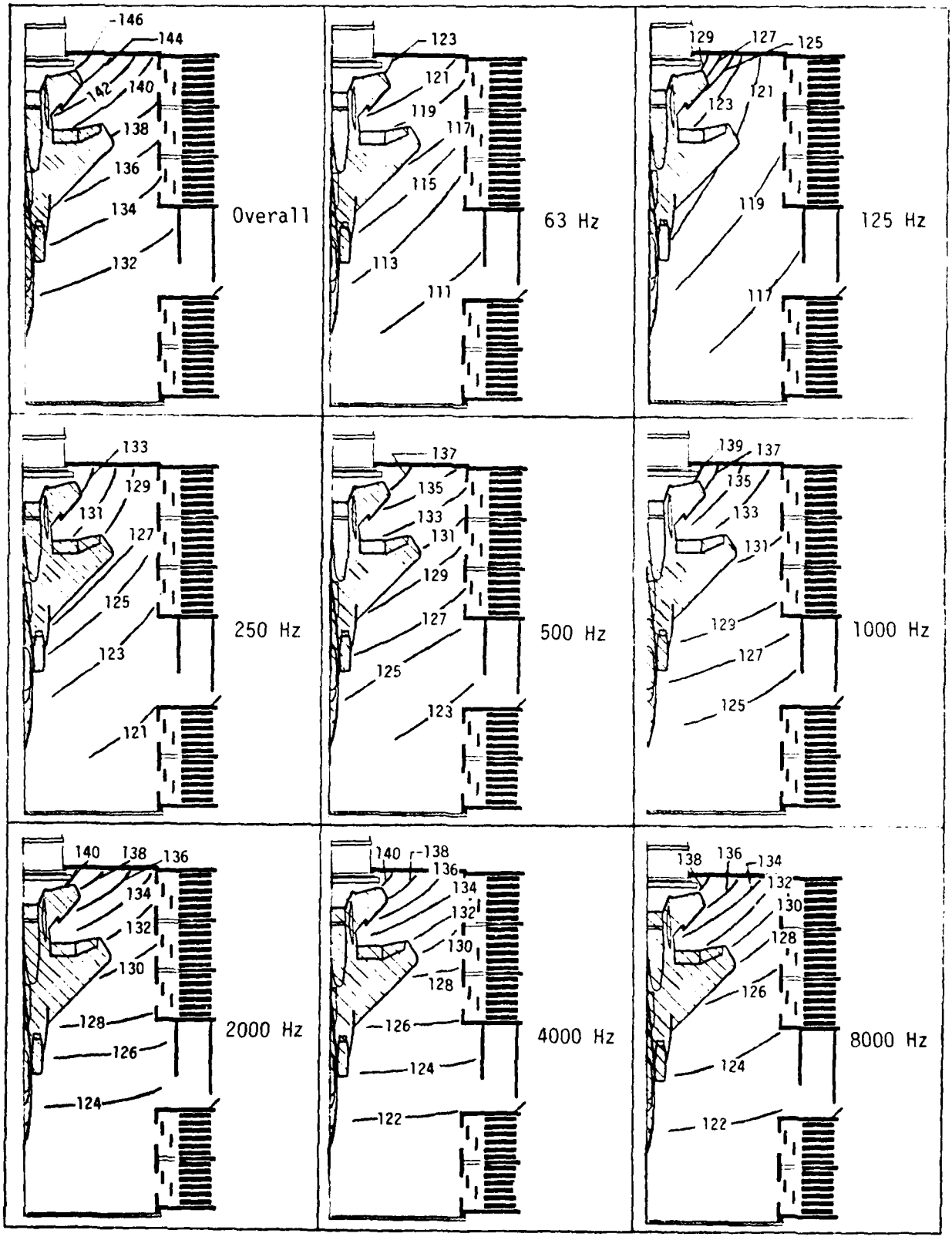
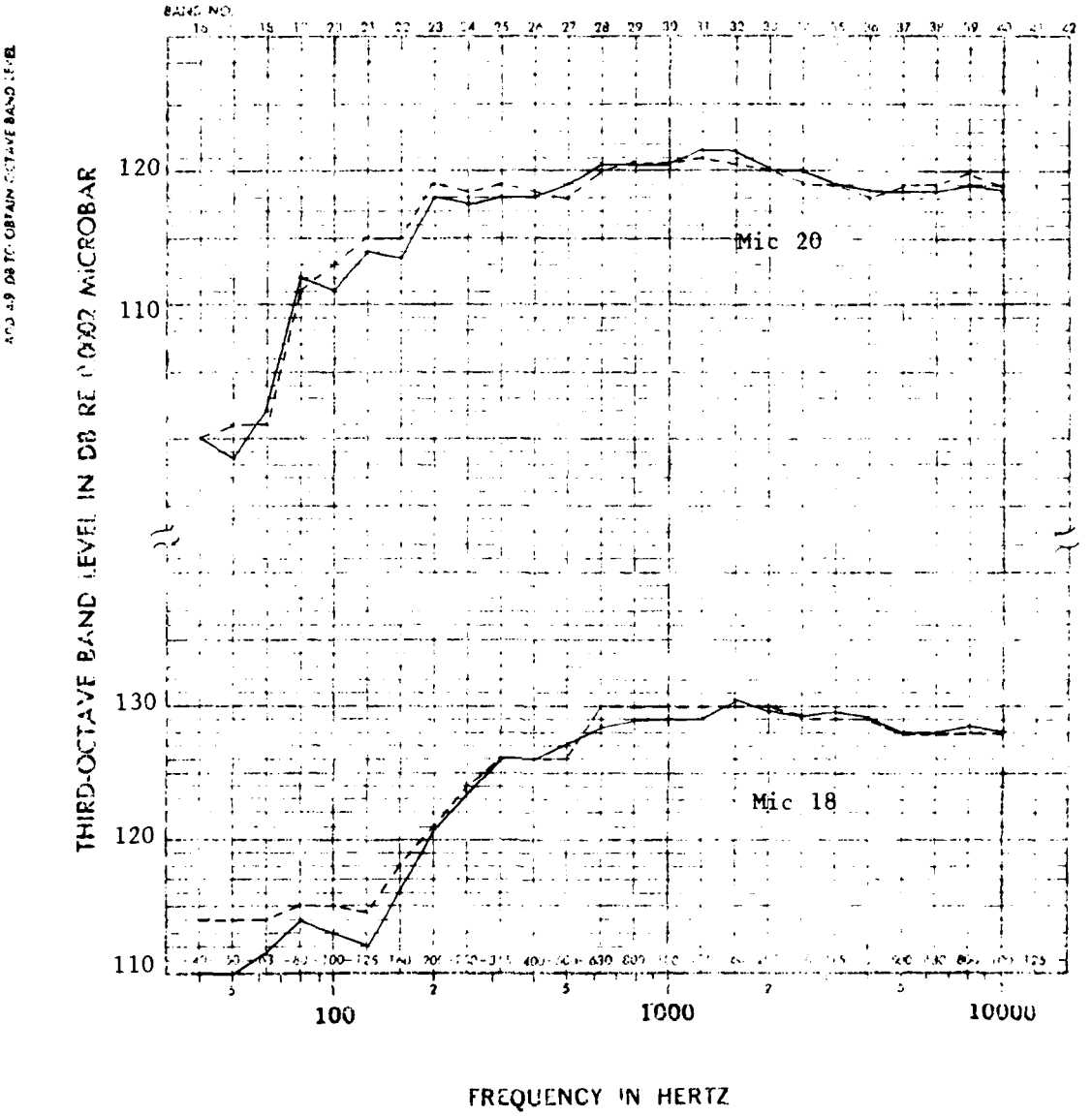


FIGURE 12 Smoothed Overall and Octave Band Contours of Equal Band Sound Pressure Level Inside Hangar Area with F-15 Aircraft Operating Left Engine at Maximum Afterburner and Right Engine at Idle.

the hangar area could be realized; however, clearance problems associated with the vertical and horizontal stabilizers preclude this.

Note also that the distance between the SPL contours in the back portion of the hangar area tends to decrease with increasing frequency. This is indicative of the increased absorption at the higher frequencies provided by the acoustically treated hangar walls.

The effect of opening the large hush house hangar doors on the sound pressure levels in the hangar area is shown in Figure 13. The two microphone locations shown on this figure reveal that little change in SPL takes place. This effect is similar at other locations in the hangar. Opening these doors, therefore, has little effect on the noise environment inside the hangar. However, opening the doors increases the far field noise levels in the quadrant forward of the hush house and could necessitate the need for ear protection for personnel stationed there.



——— Record 14; Lt. Eng. Max. A/B; Rt. Eng. Idle; Hush House Doors Closed

------ Record 10; Lt. Eng. Max. A/B; Rt. Eng. Idle; Hush House Doors Open

FIGURE 13 Comparison of Noise Environment in Hush House Hangar Area with Doors Open and Closed.

V. CONCLUSIONS

1. No structural damage due to sonic fatigue is anticipated with the F-15 aircraft structure during operation in the hush house hangar area at maximum afterburner power.

2. The noise field impinging on the F-15 aircraft structure above 250 hertz is greater in the hush house than on a concrete pad in the free field. This increase could affect equipment, avionics, etc.

3. The sound pressure levels measured on the F-15 aircraft are 2 to 11 dB less below 1000 hertz at similar locations than those measured in existing F-15 wet-cooled noise suppressors.

4. The hush house muffler attenuates the 63 and 125 hertz octave band sound pressure levels radiating to the far field so that the SPL are 6 dB less than the requirements for a grade II type noise suppressor.

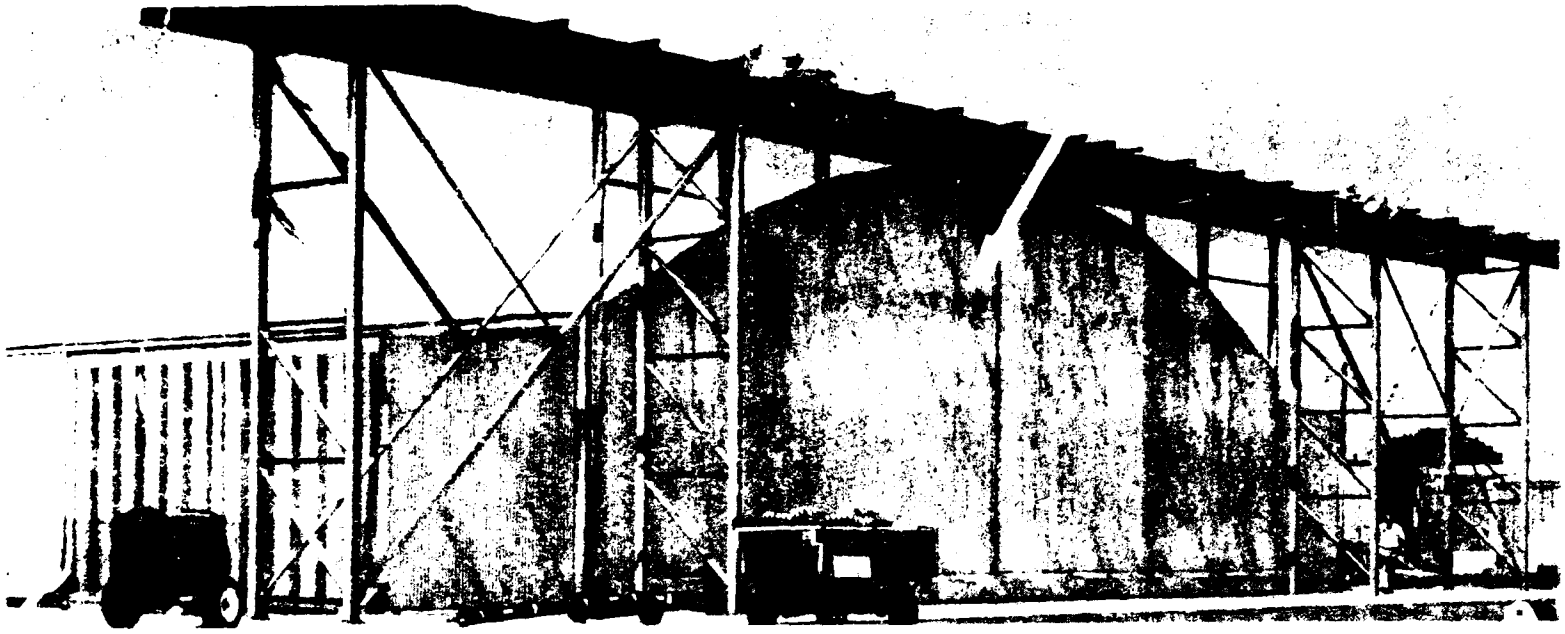
5. Ear protection will be needed for personnel stationed in and around the F-15 aircraft while operating in the hush house, but should not be needed for the control room.

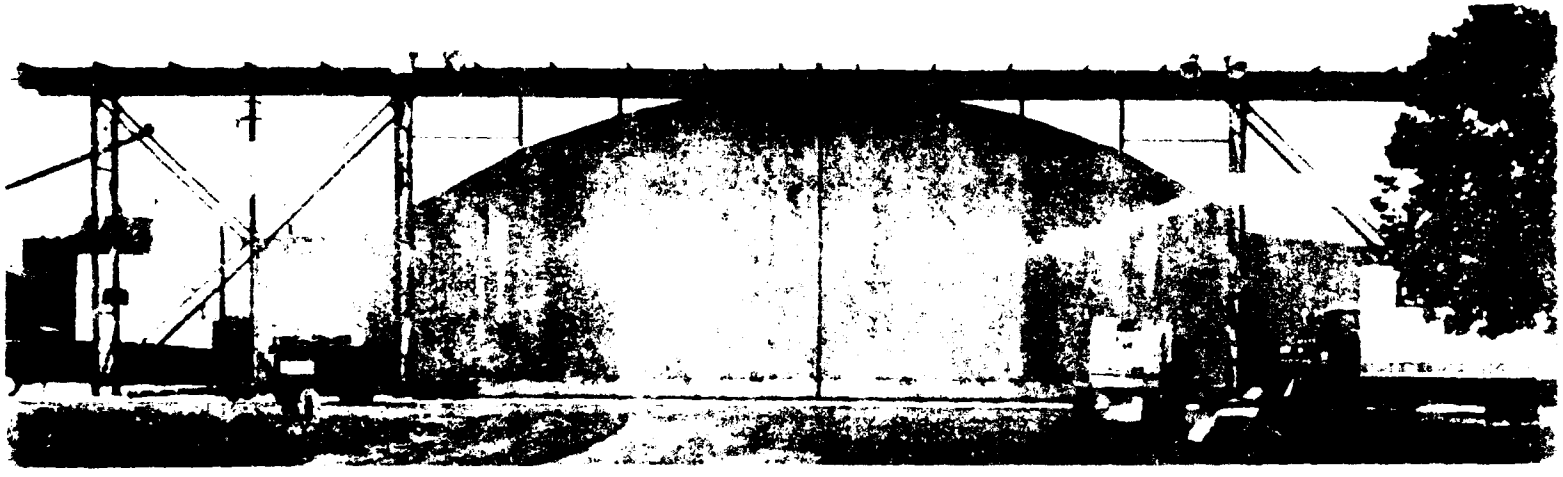
VI. RECOMMENDATIONS

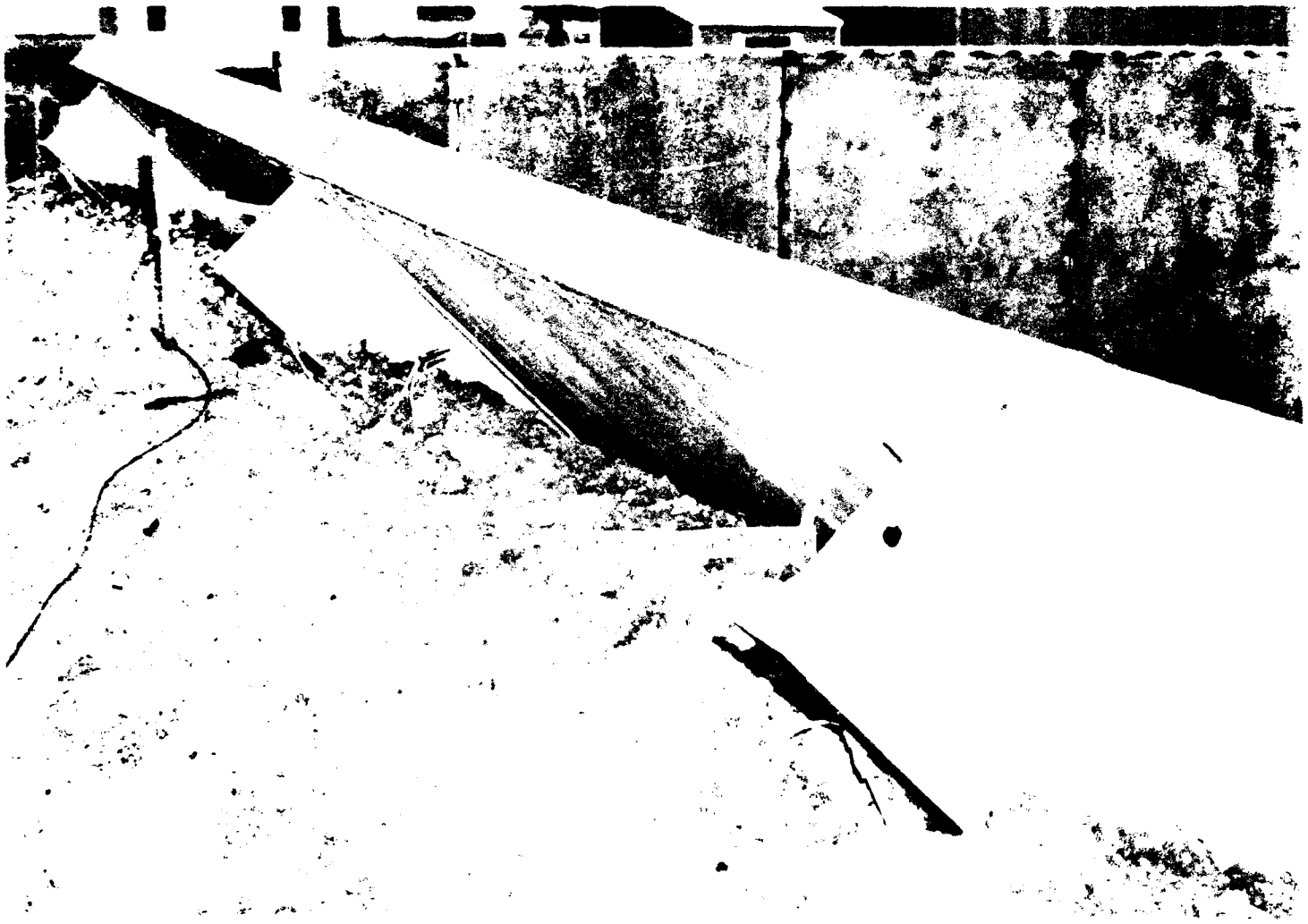
1. F-15 aircraft equipment qualification levels should be checked against the sound pressure level increases measured in the hush house hangar area to determine if the equipment has been qualified for this type of operation.
2. If vibration qualification test requirements are desired for internal avionics, then response predictions should be made based on the acoustic measurements obtained during this program.
3. Hearing protection should be worn by personnel in close proximity to the F-15 aircraft while operating in the hush house.

APPENDIX A: PHOTOGRAPHS OF TEST SET-UP

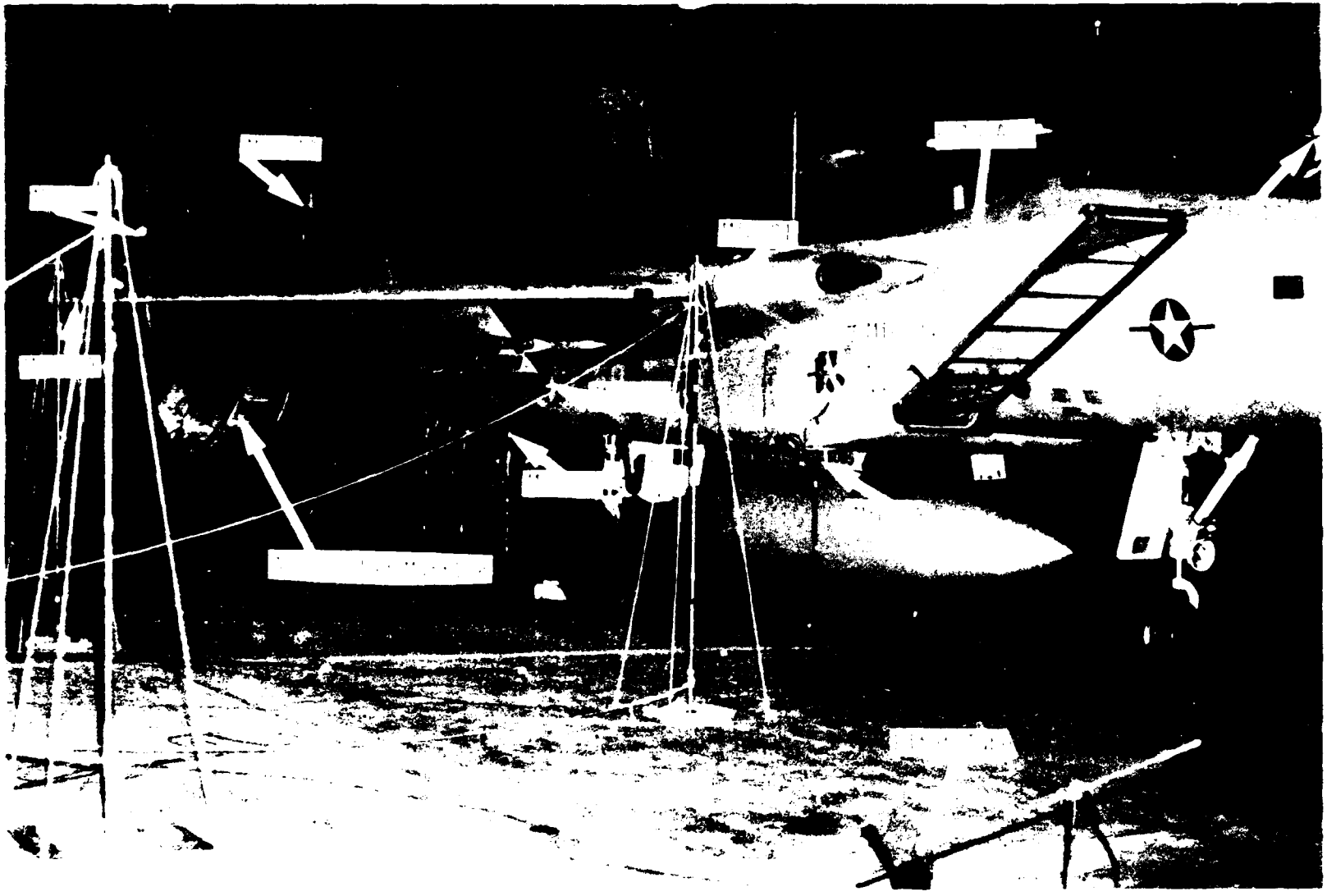
Some of the photographs which were taken at the test site are included here. These photographs will serve to give the reader a better idea of where transducers were located, how the aircraft was positioned in the hush house, etc. These photos were furnished couresty of the Base Photography Branch at Kelly AFB, Mr. M. A. Hart of AFWAL, and Mr. R. J. Reilly, consultant to ASE, Inc.







Location of Microphone in Boat to Rear of Bow Deflector




LA

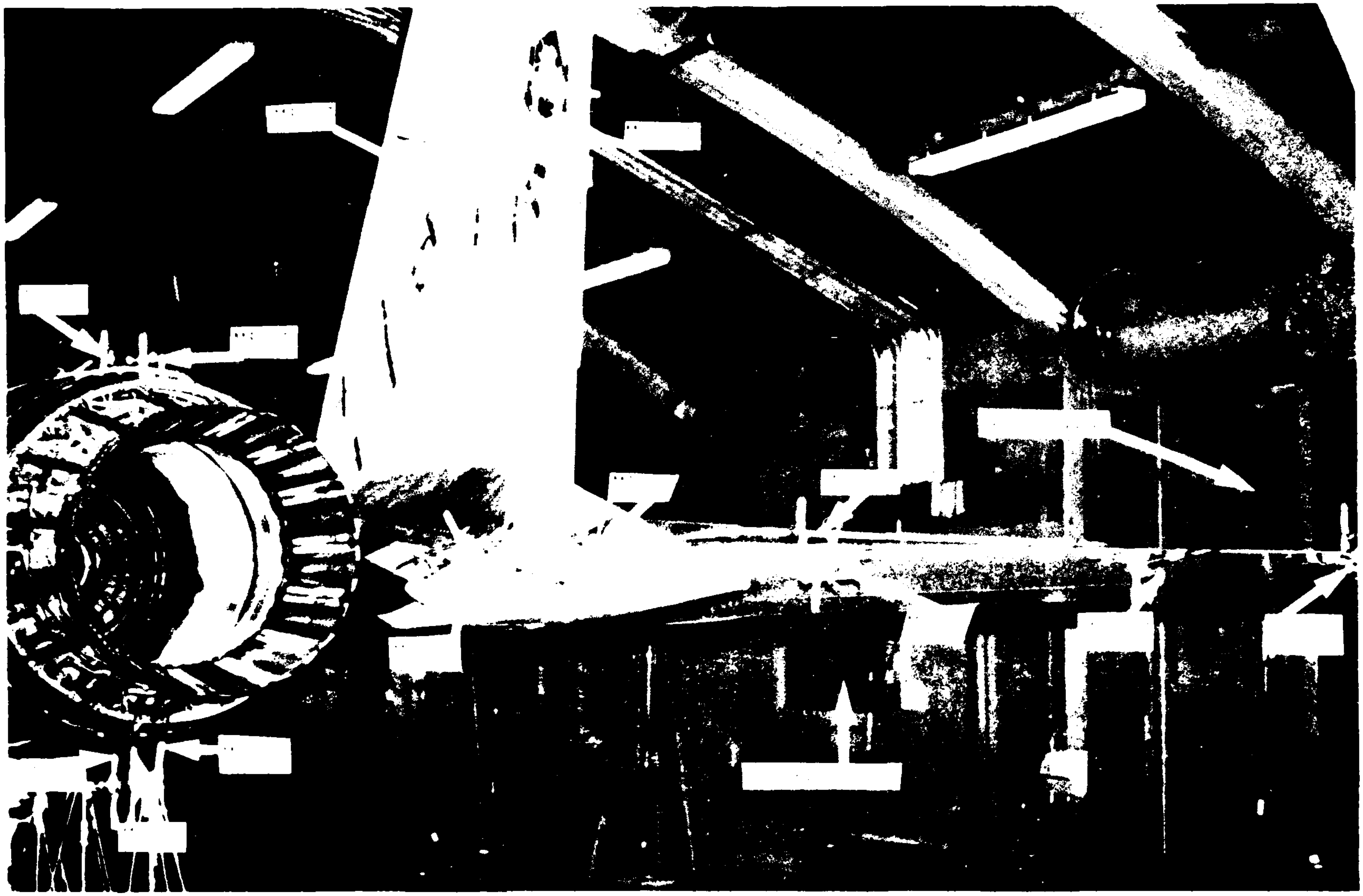


FIGURE 38. Location of Microphones 1-12, [illegible]

FIGURE [illegible] [illegible] Aircraft During Maximum Afterburner Operation in Blast House

APPENDIX B. REDUCED DATA

The data which were recorded and analyzed from the test and identified in Table 1 are included here. The octave band sound pressure levels for 24 of the microphones are shown in Figures B1 through B24 for Record Numbers 4, 5, 9, and 10. Corresponding one-third octave band levels for the same microphones are shown in Figures B25 through B48 for Record Numbers 3, 4, 5, 9, 10, and 12. Figures B49 through B56 show one-third octave band spectra for Record Numbers 13 and 14 for seven different microphones. A-weighted one-third octave band spectra for eight microphones and Record Numbers 4, 5, 9, and 10 are in Figures B57 through B64.

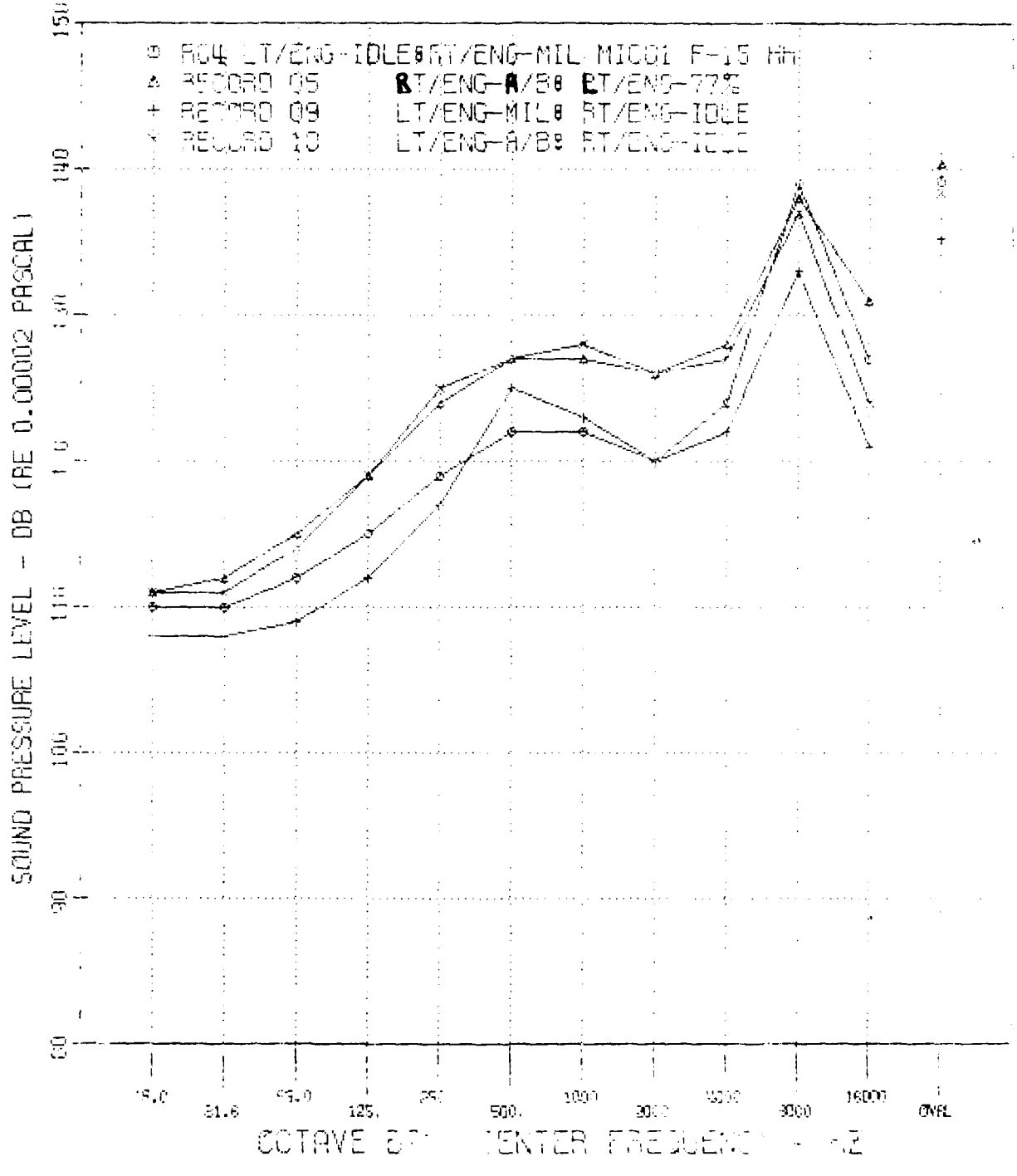


FIGURE B1 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 1.

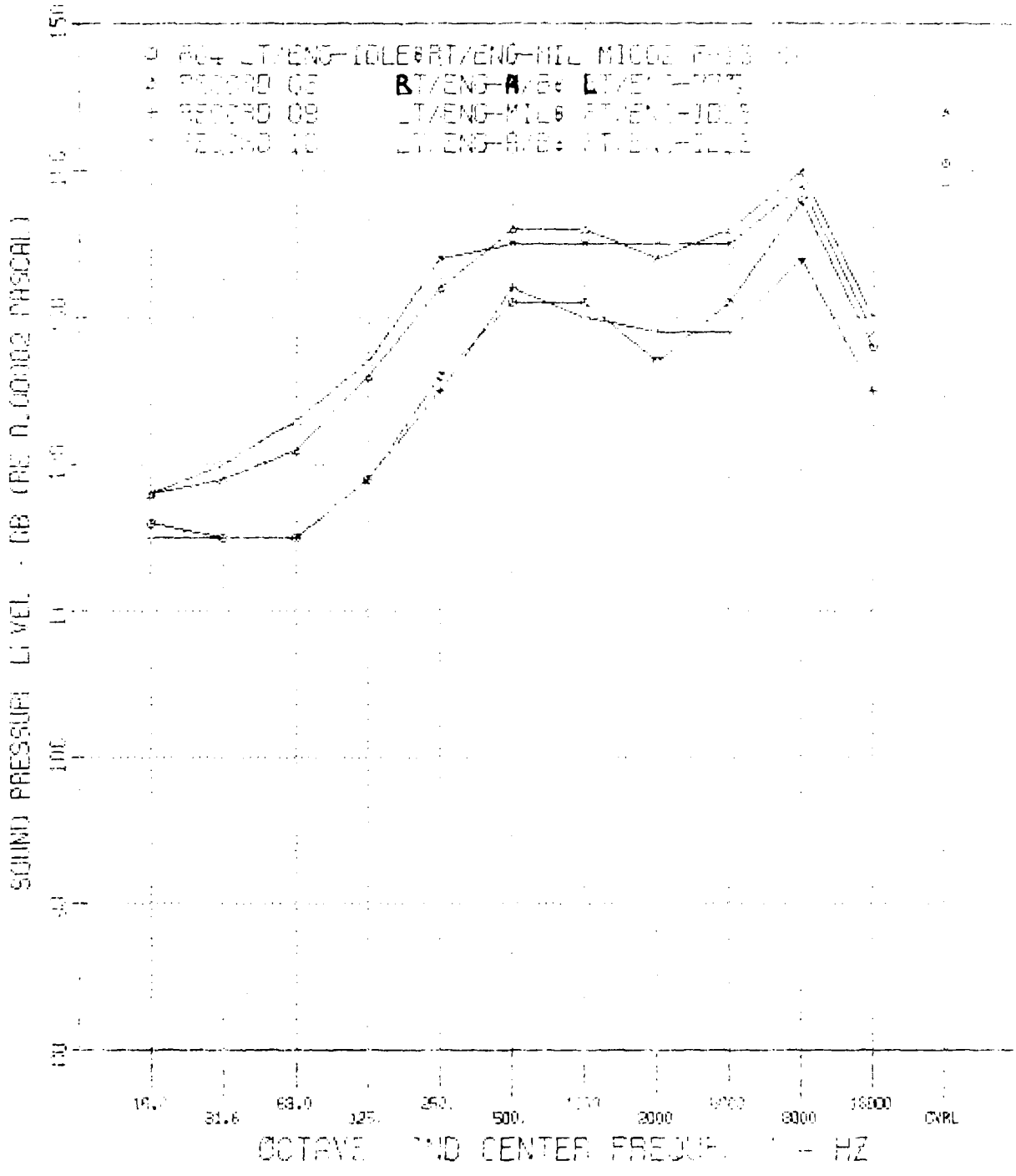


FIGURE B2 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 2.

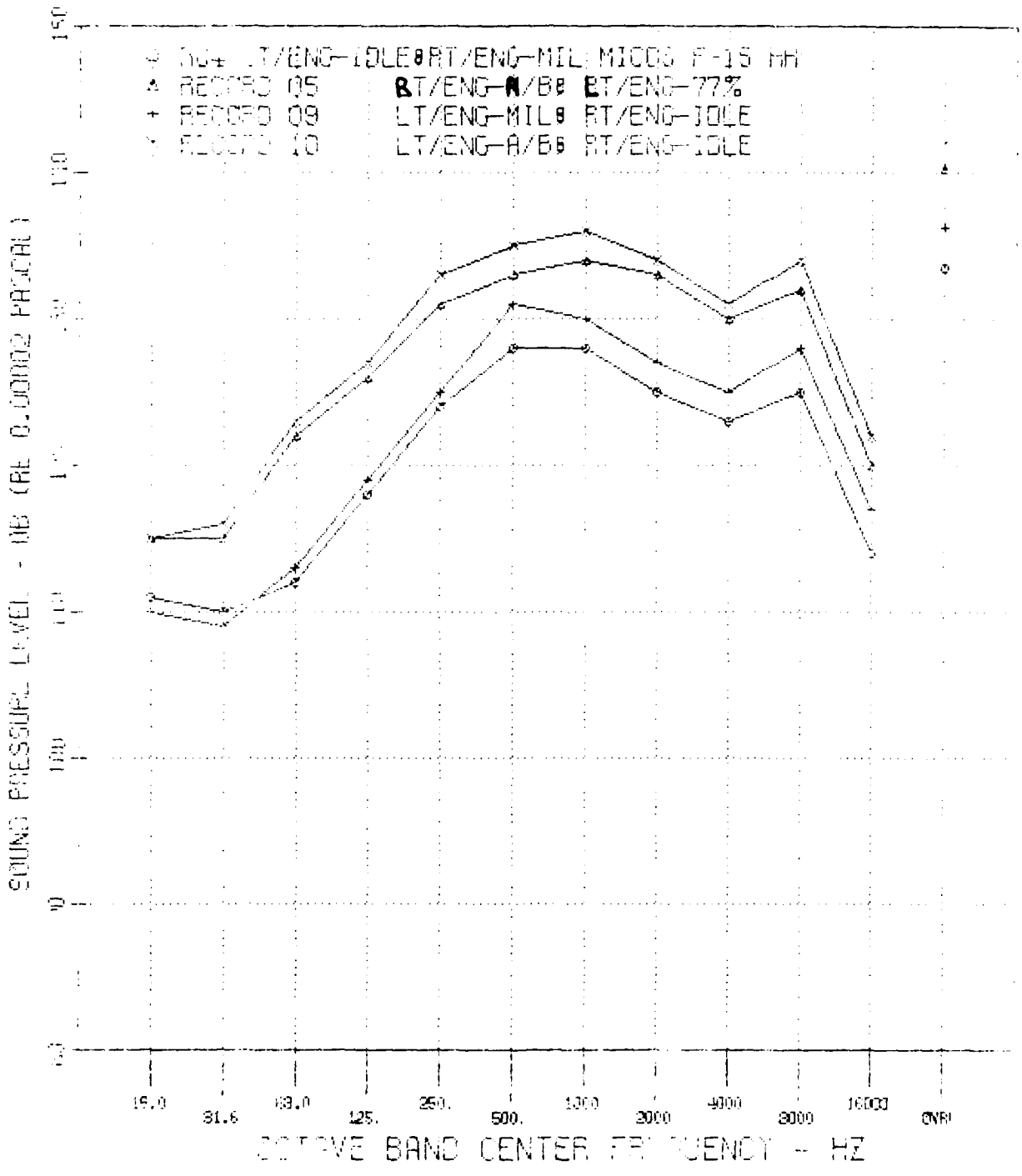


FIGURE B3 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 3.

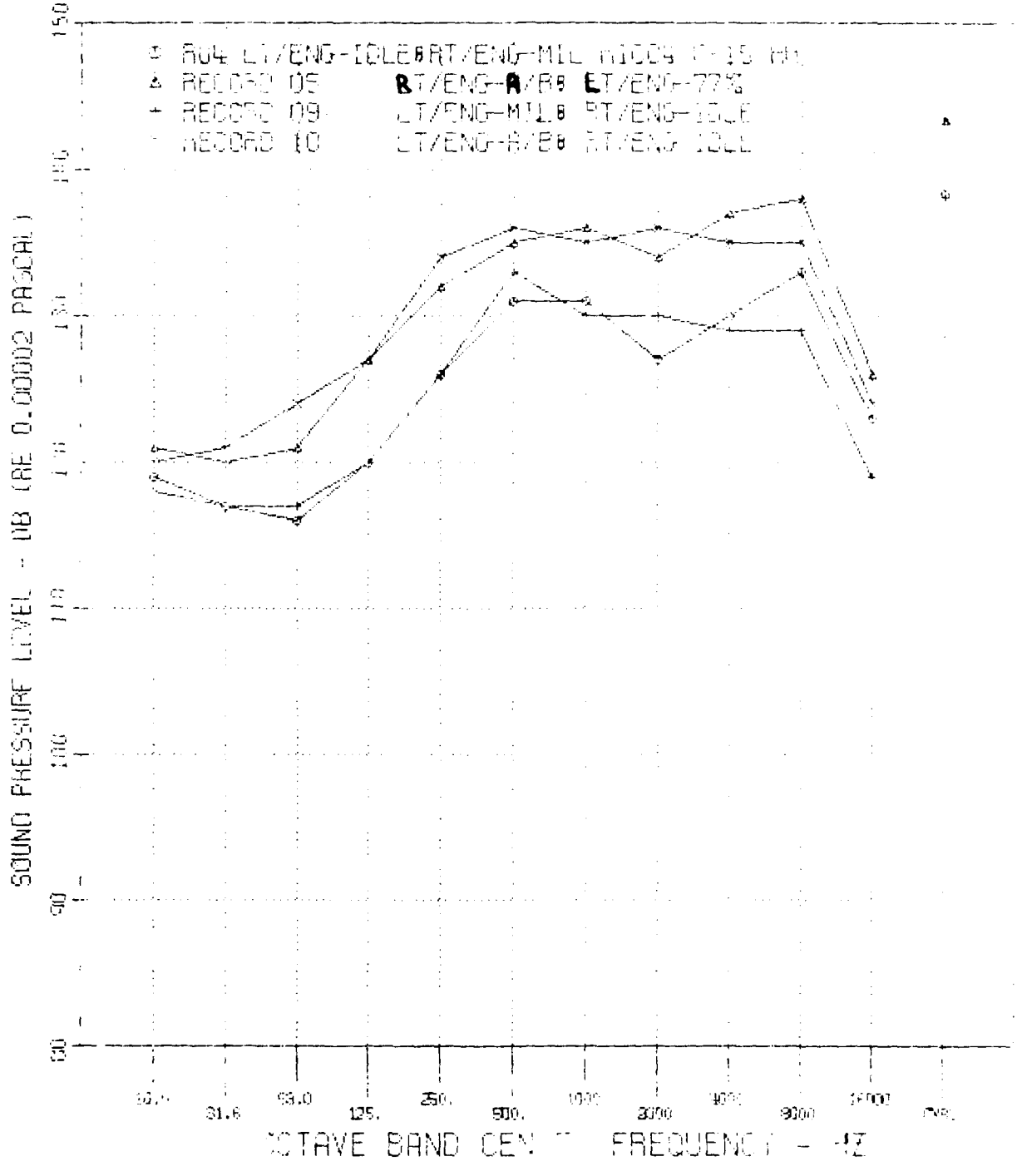


FIGURE B4 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 4.

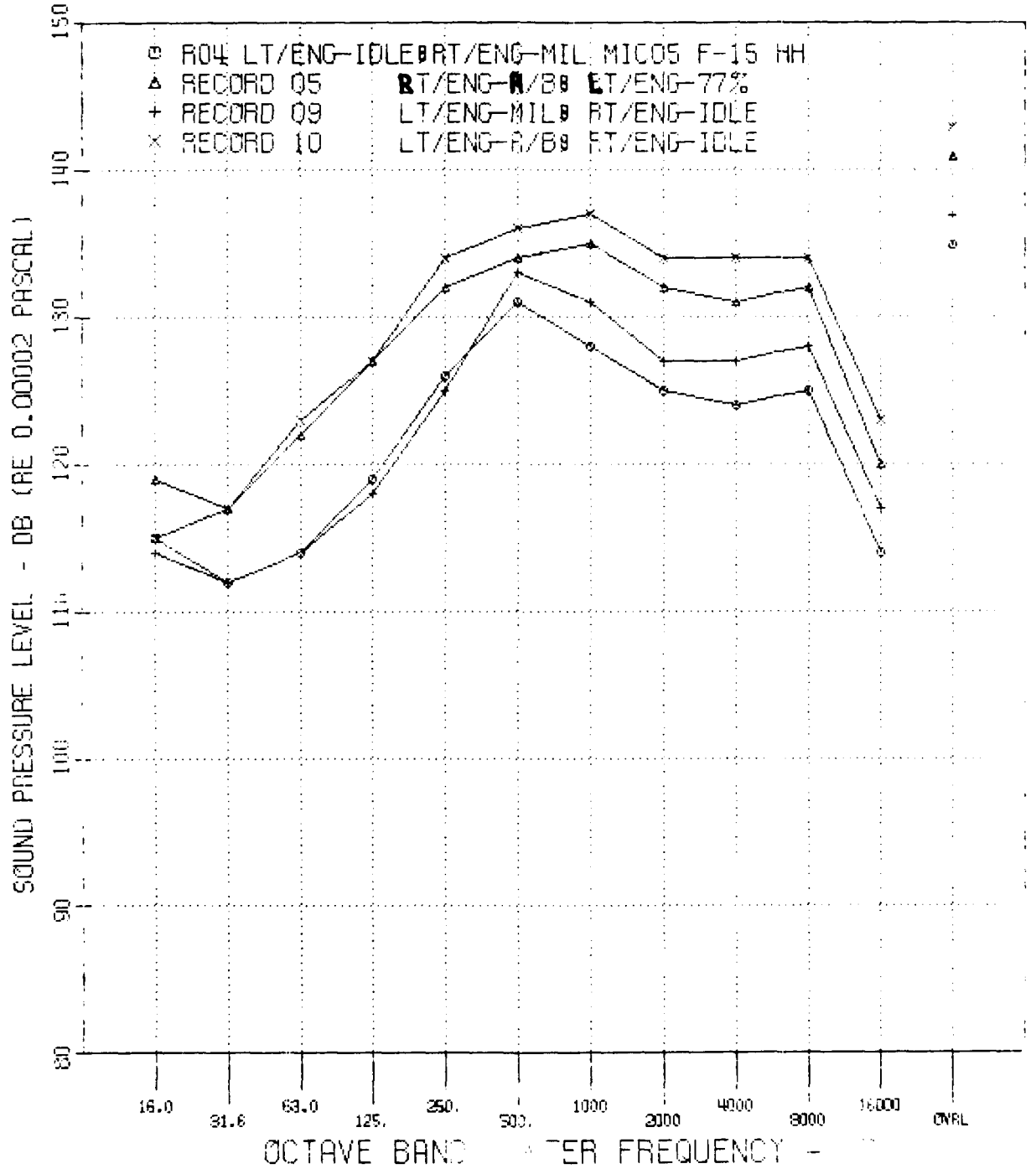


FIGURE B5 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 5.

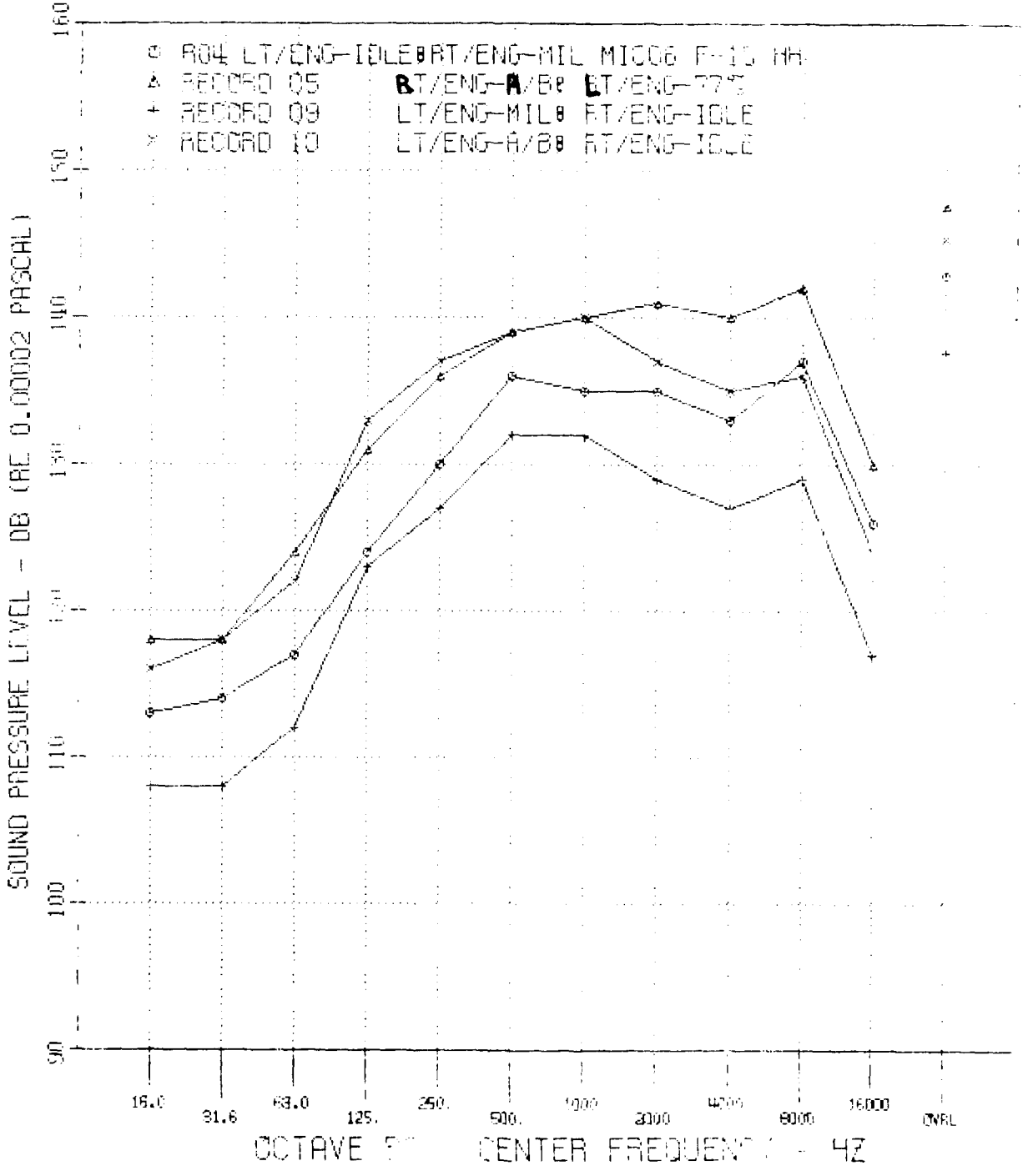


FIGURE B6 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 6.

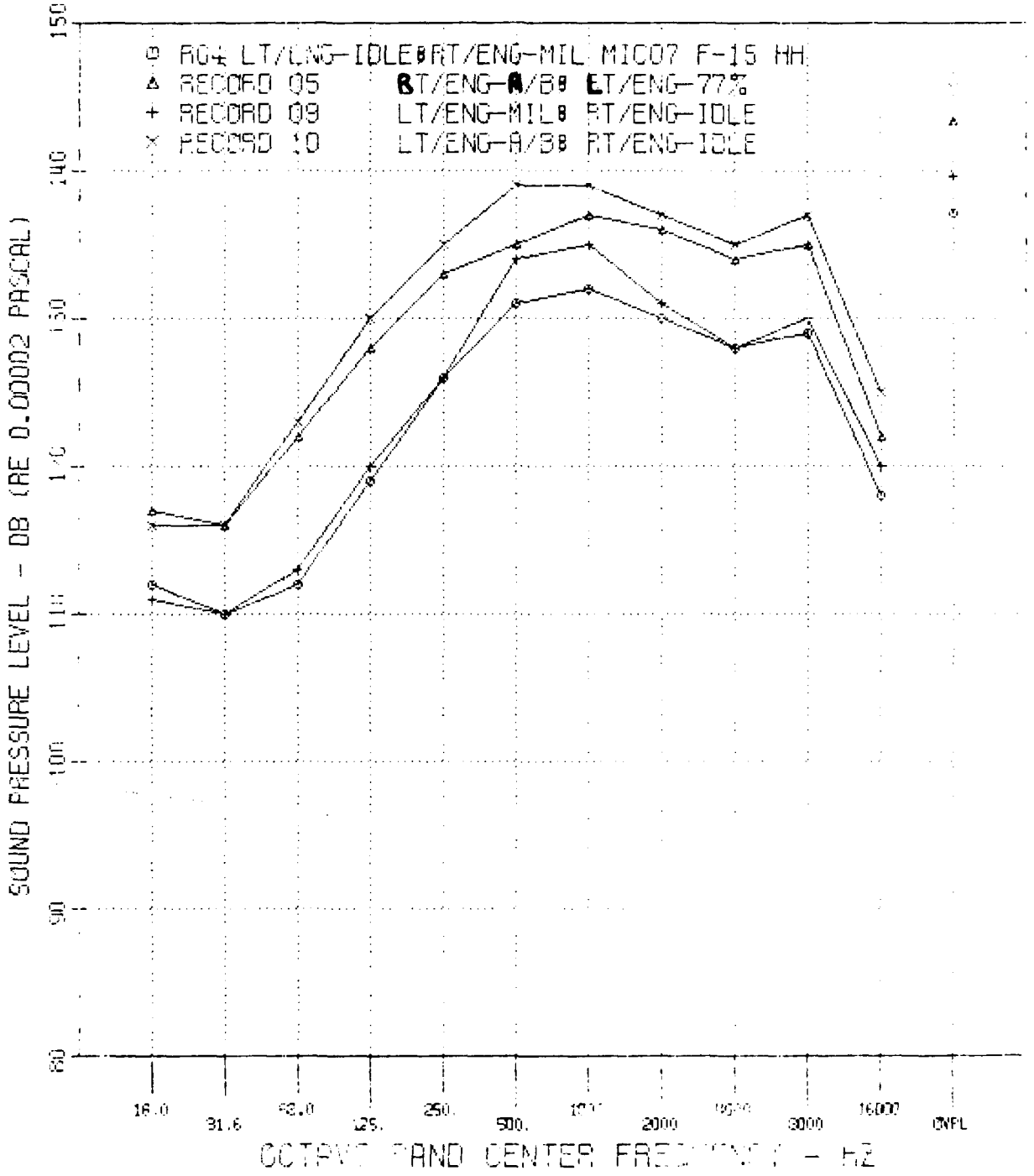


FIGURE B7 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 7

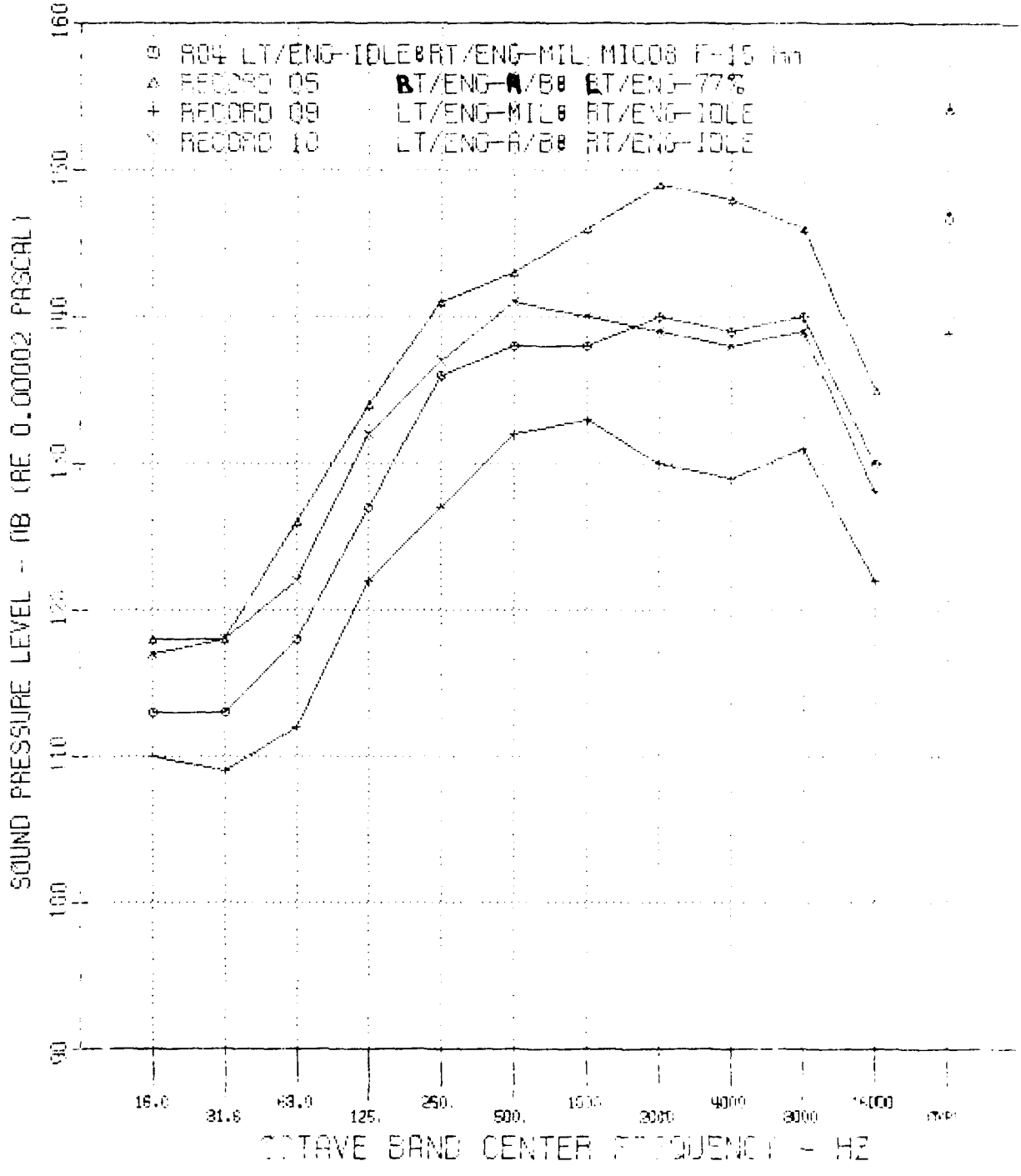


FIGURE B8 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 8.

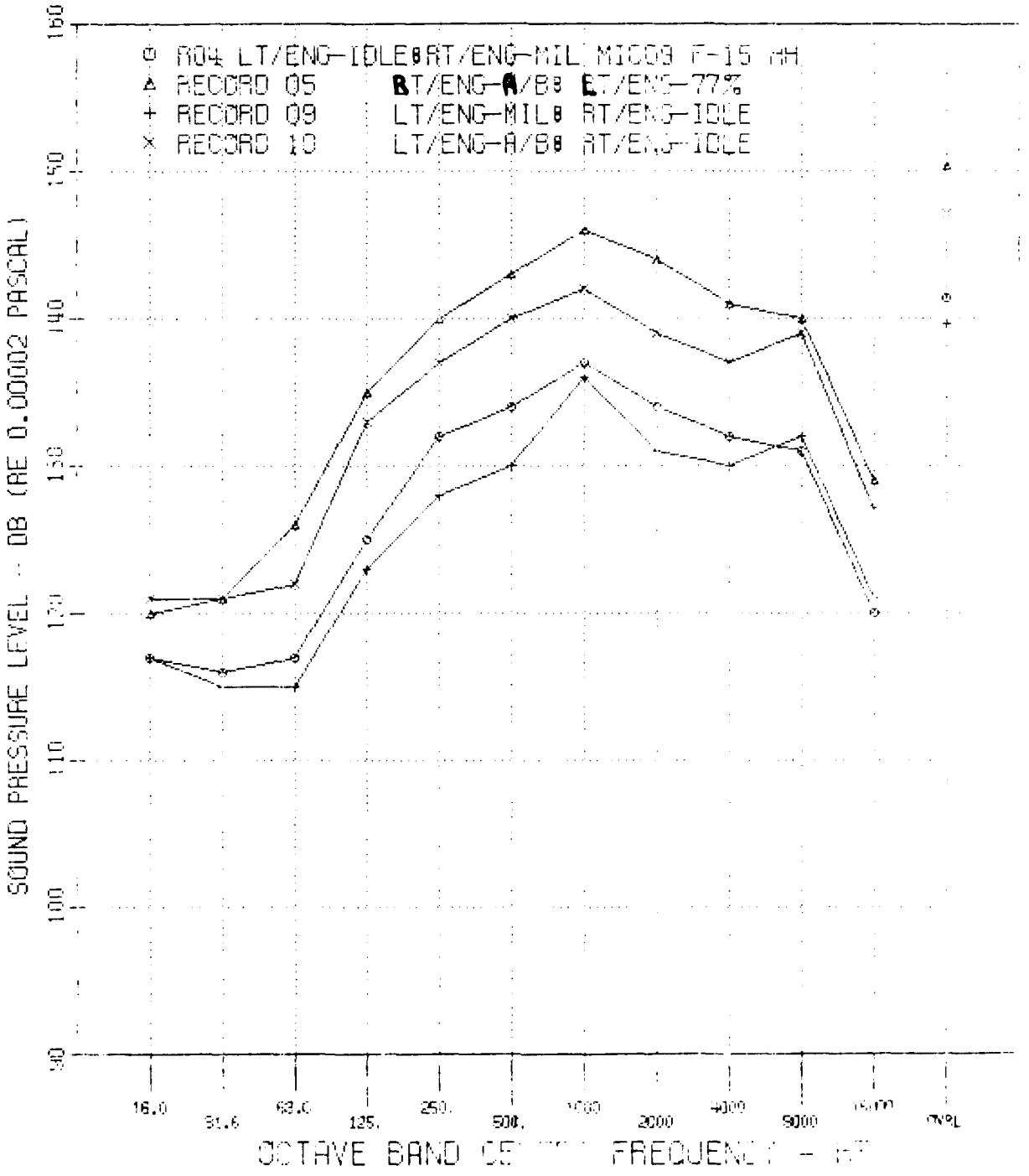


FIGURE B9 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 9.

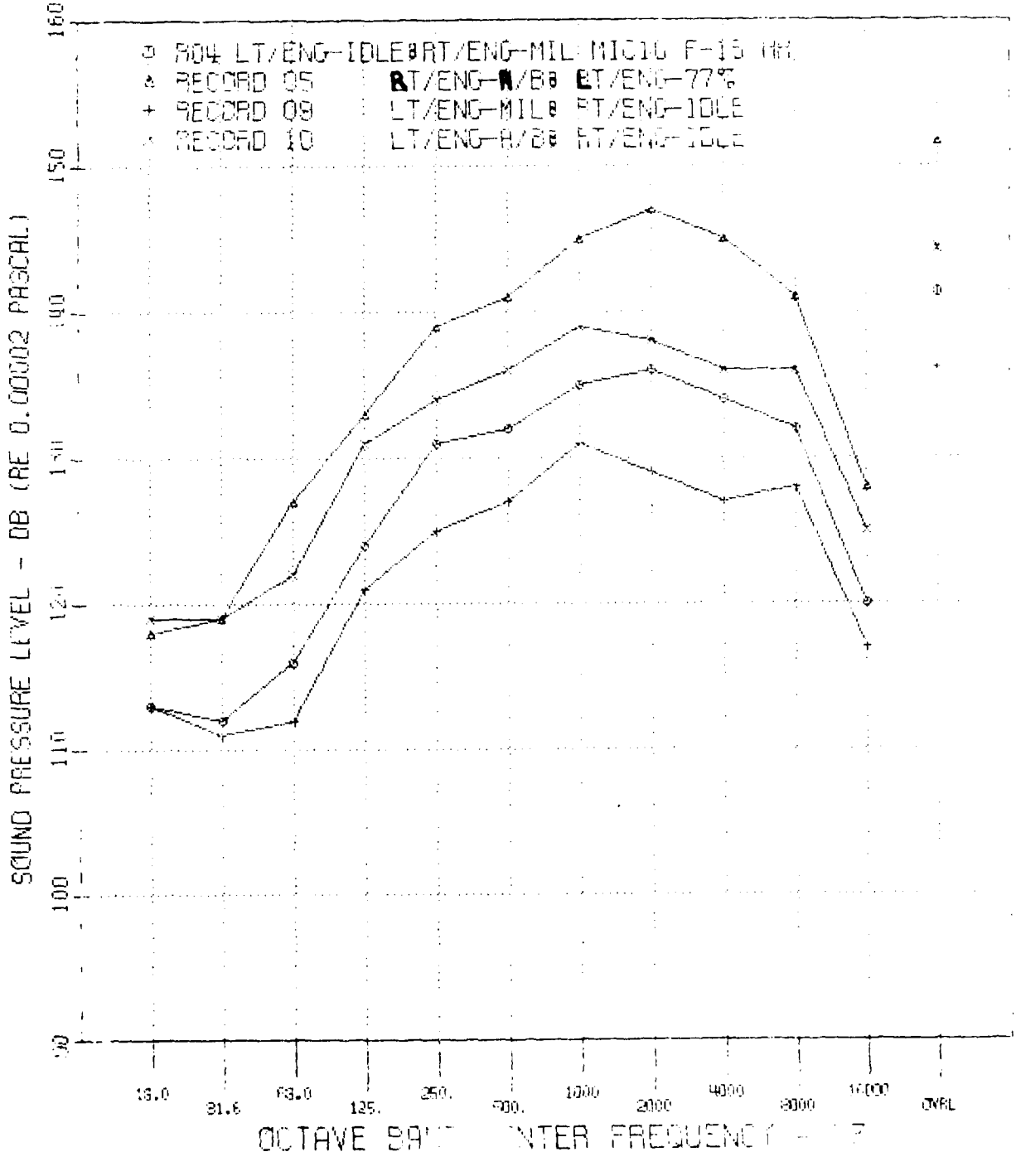


FIGURE B10 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 10.

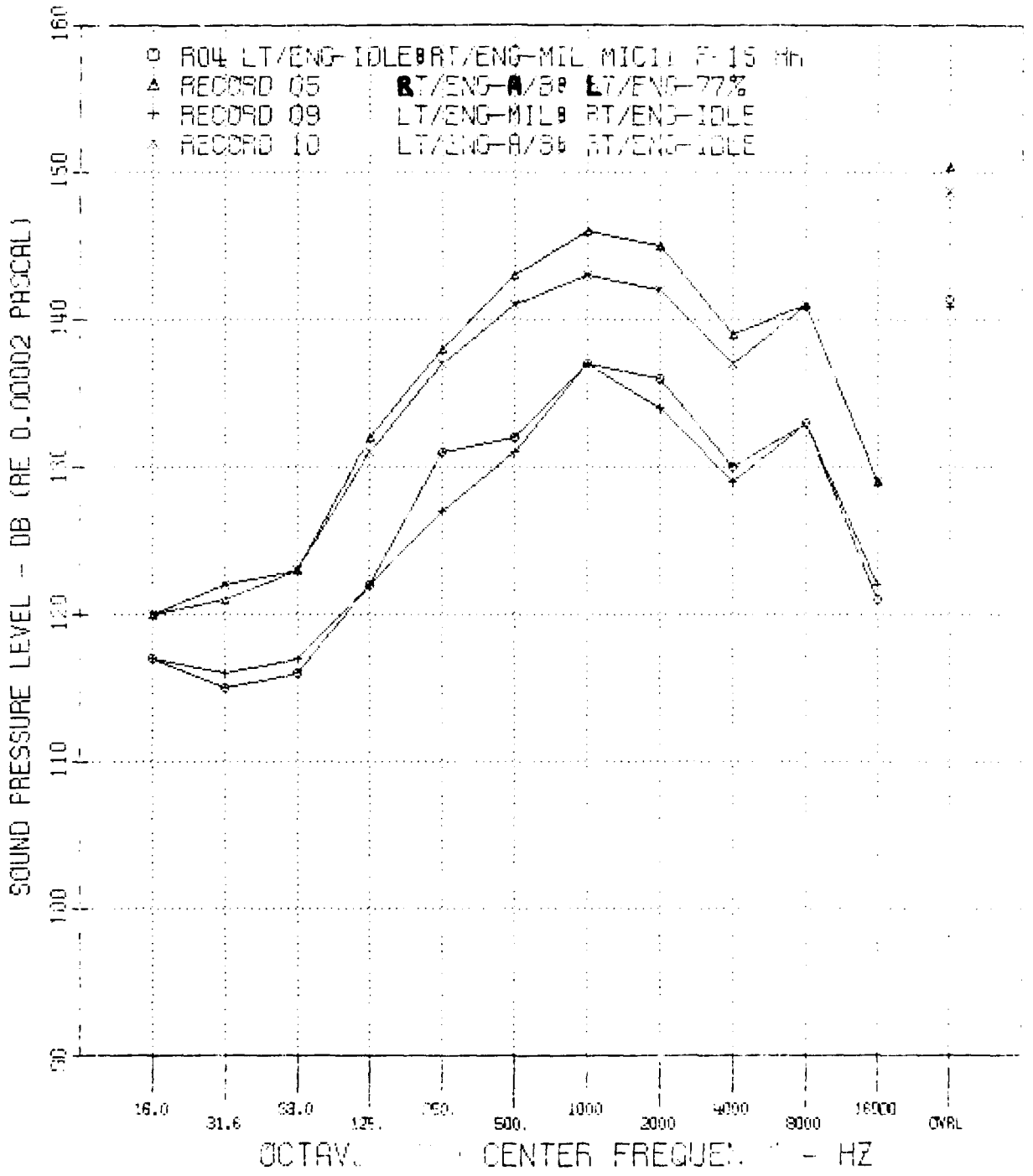


FIGURE B11 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 11.

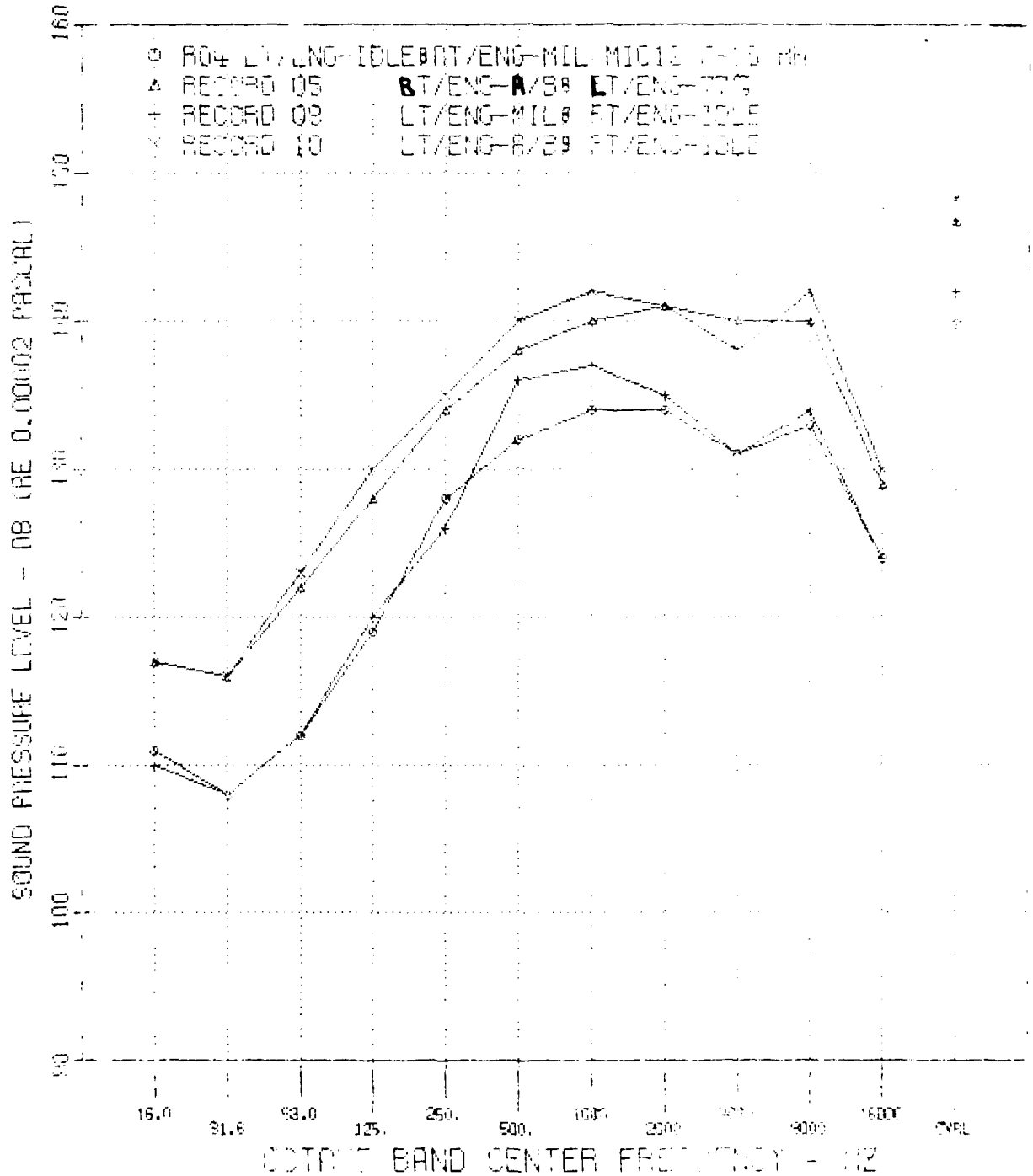


FIGURE B12 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 12

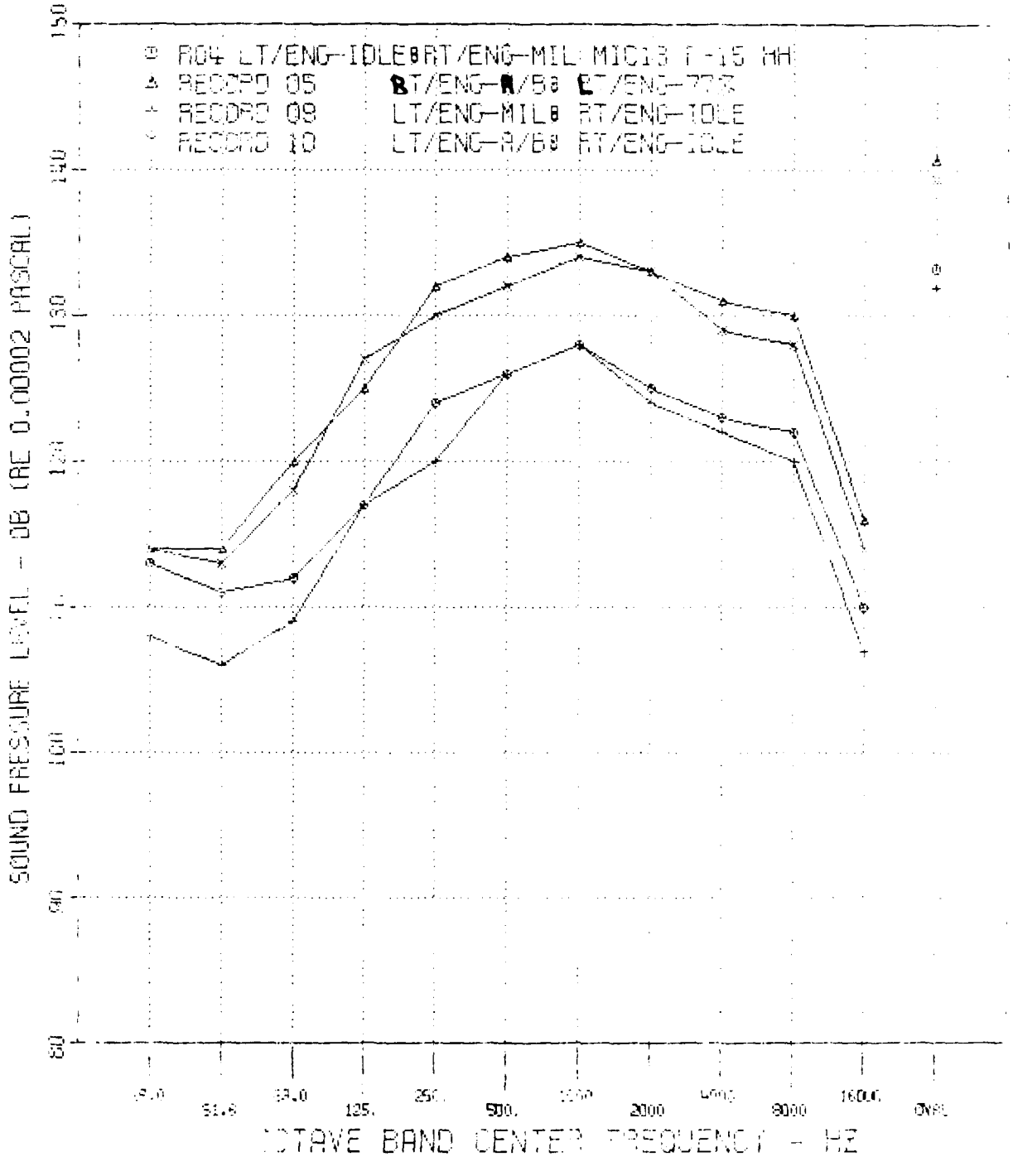


FIGURE B13 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 13.

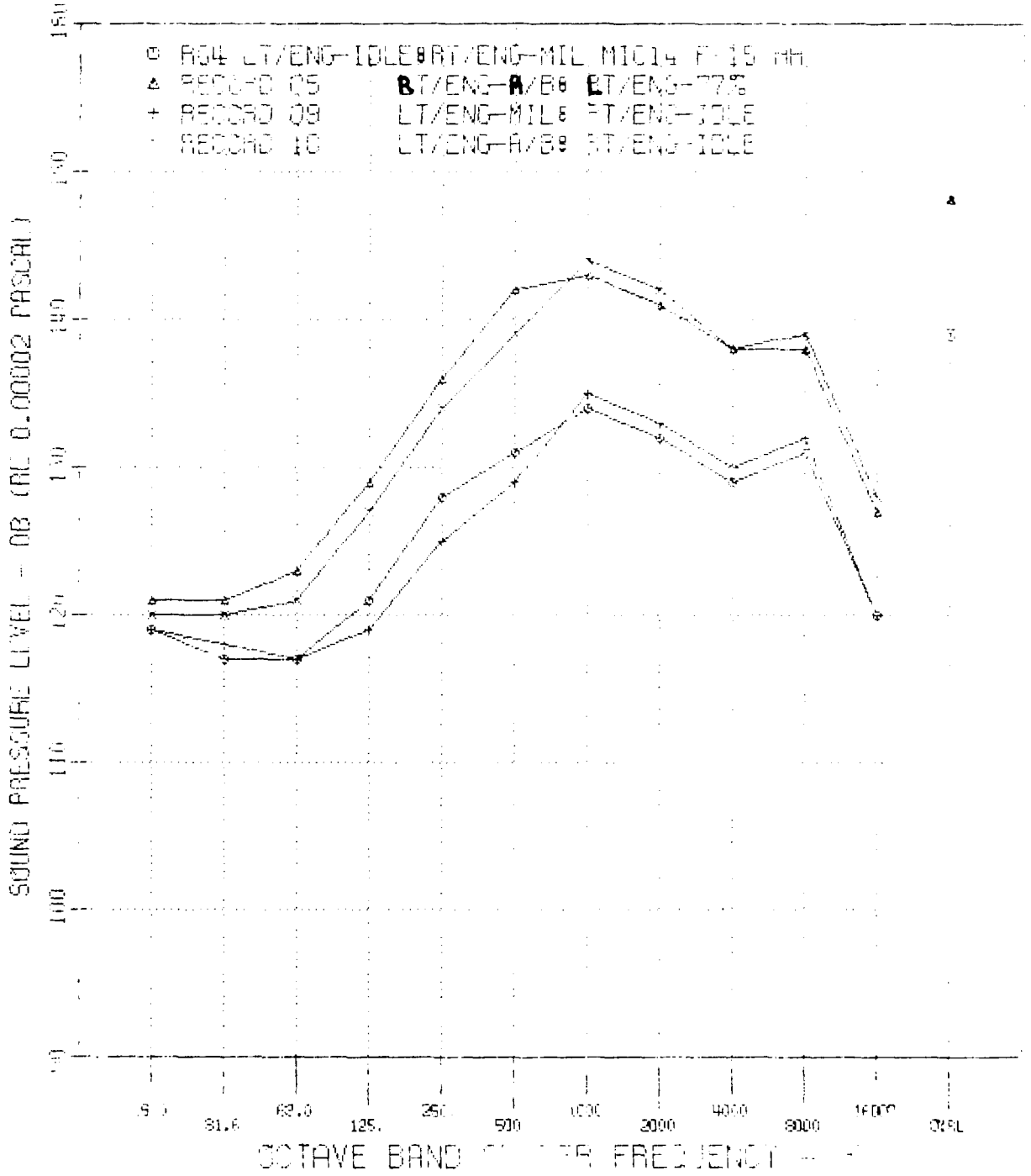


FIGURE B14 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 14.

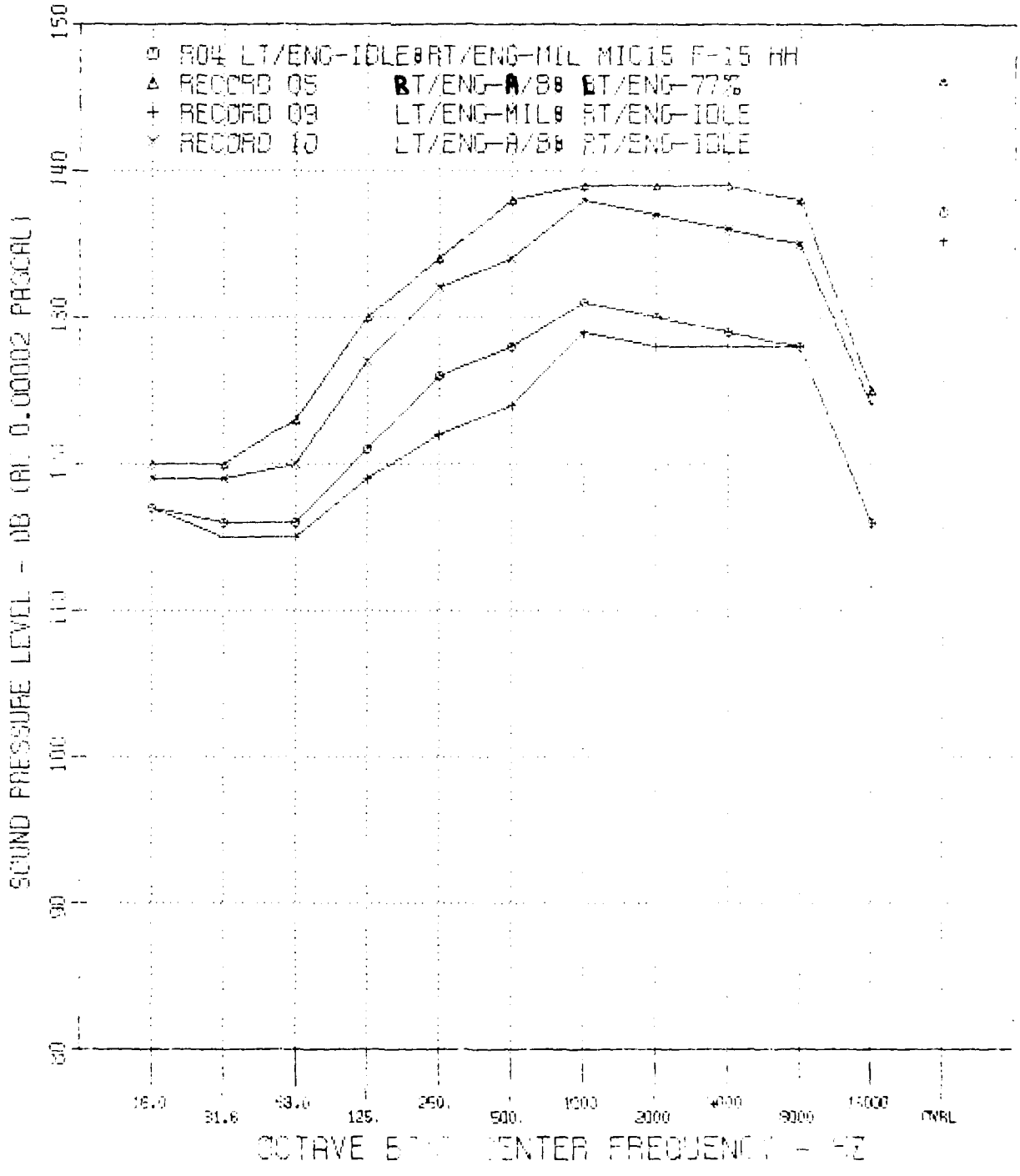


FIGURE B15 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 15.

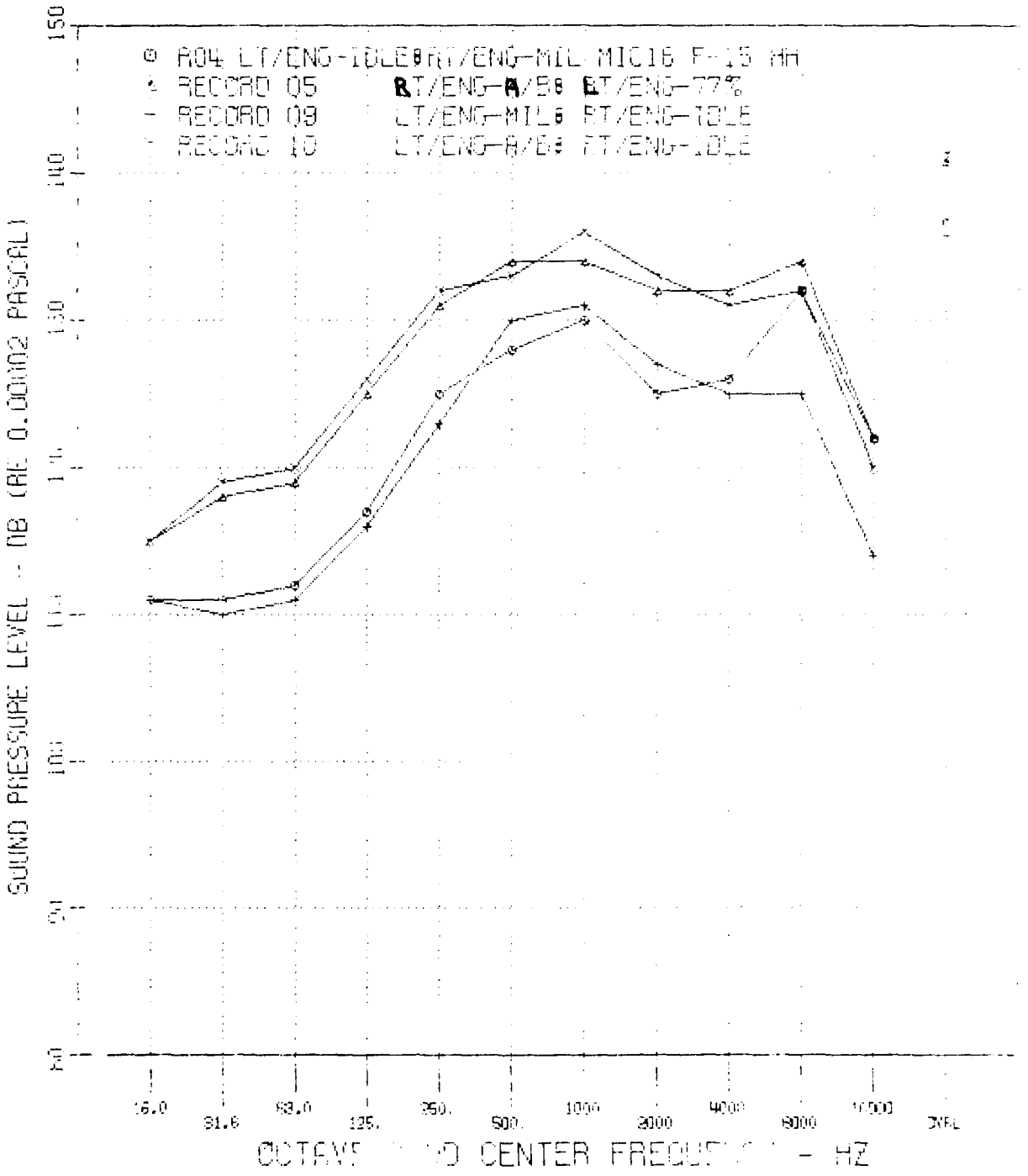


FIGURE B16 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 16.

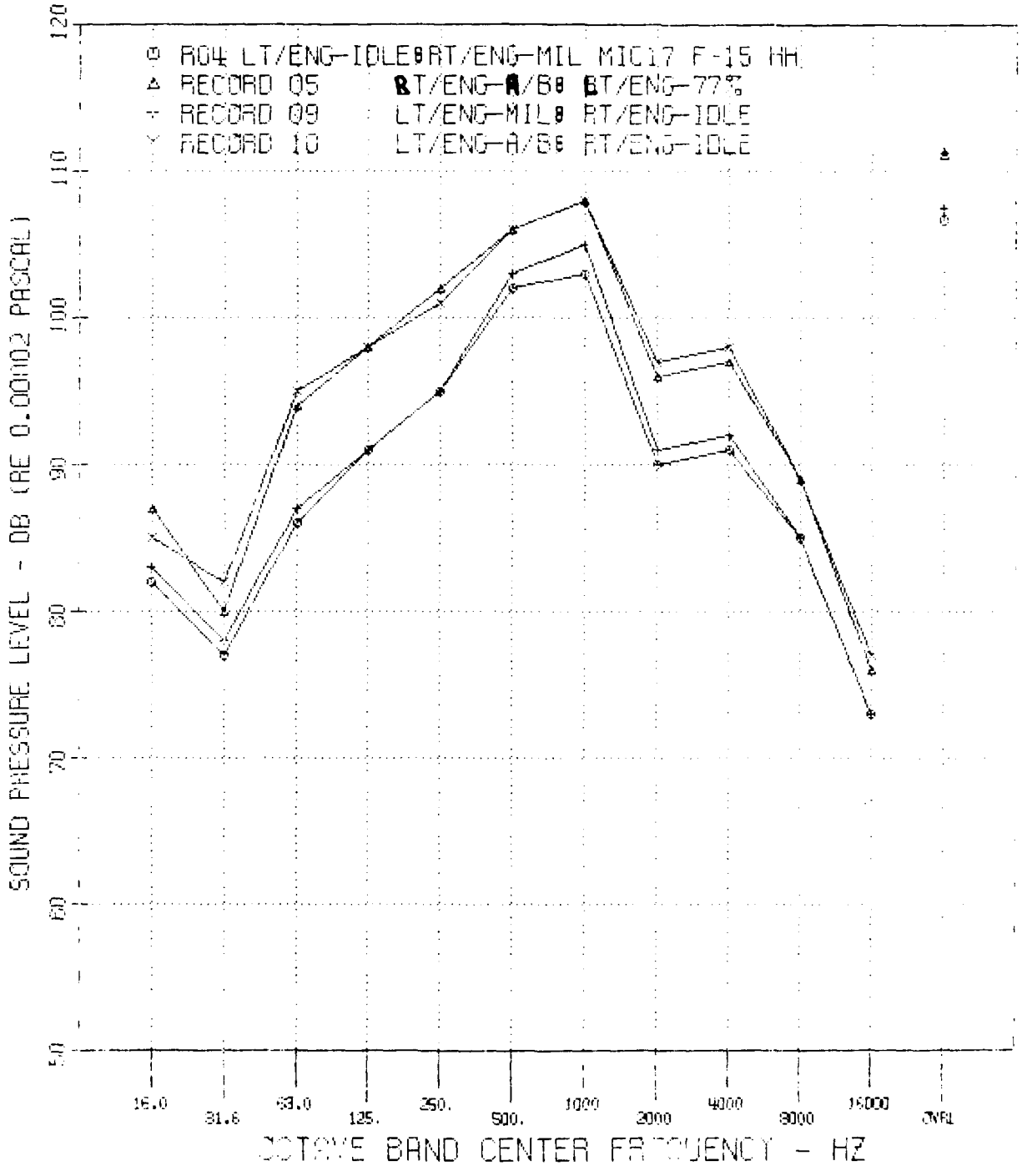


FIGURE B17 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 17.

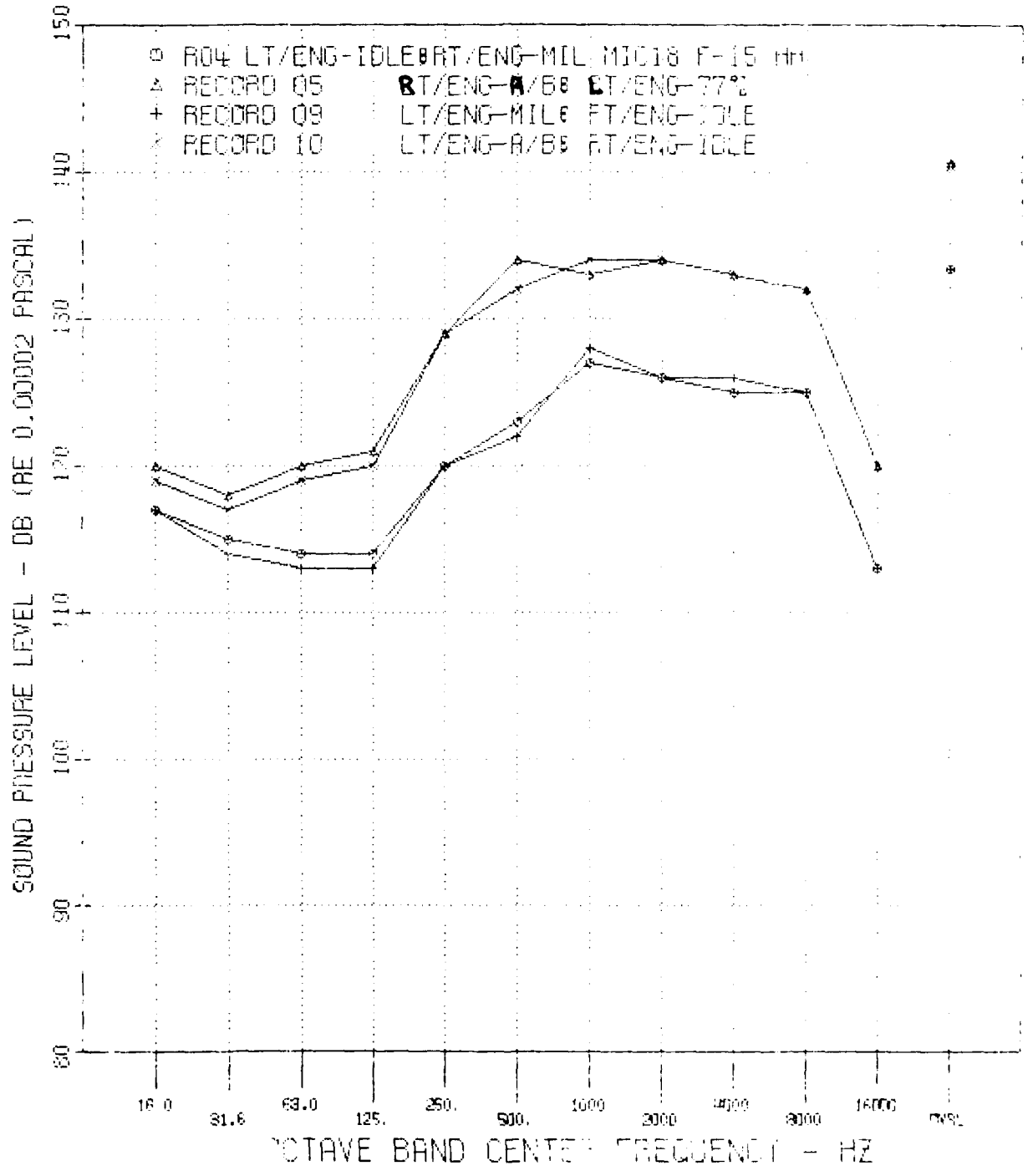


FIGURE B18 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 18.

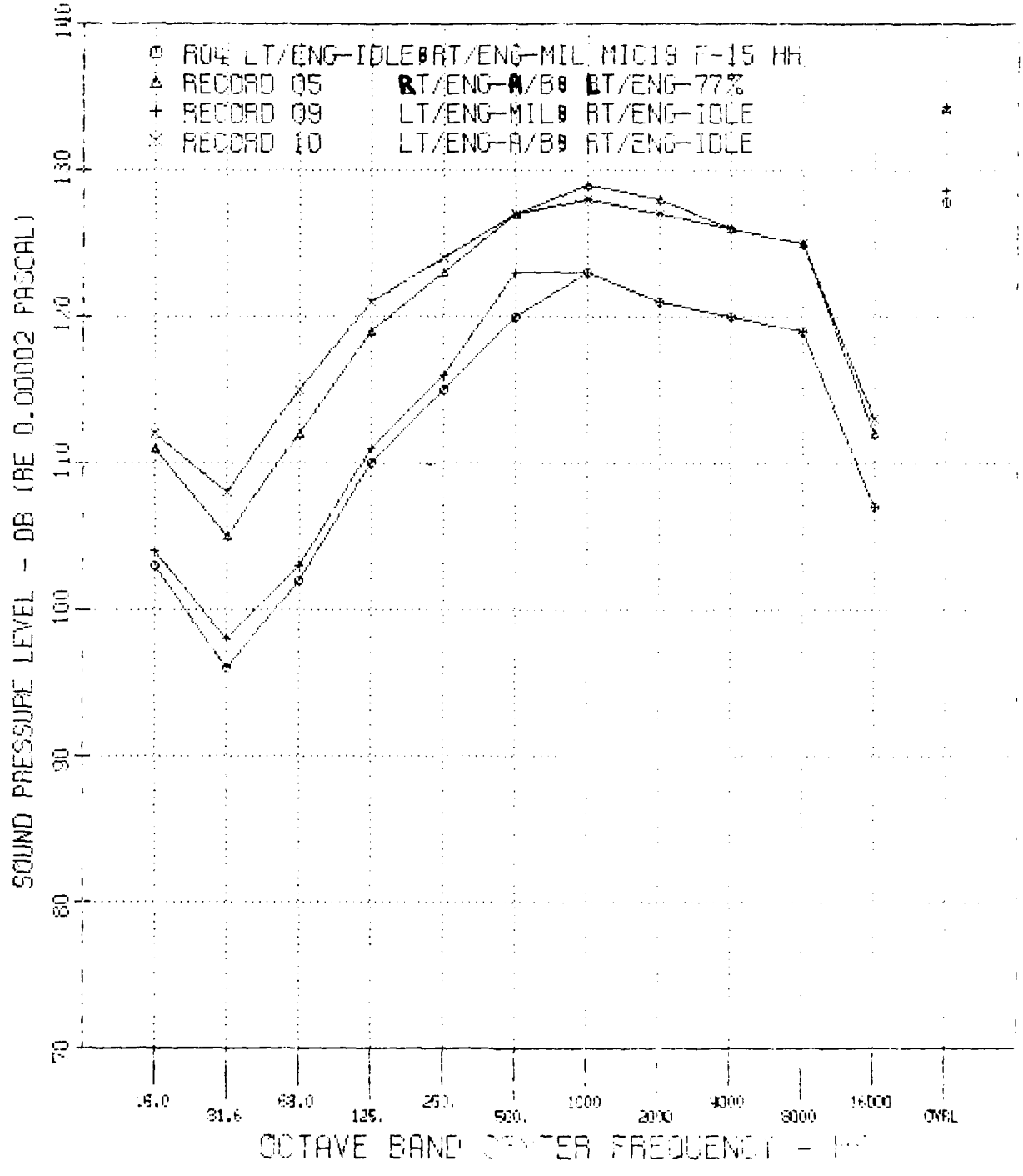


FIGURE B19 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 19.

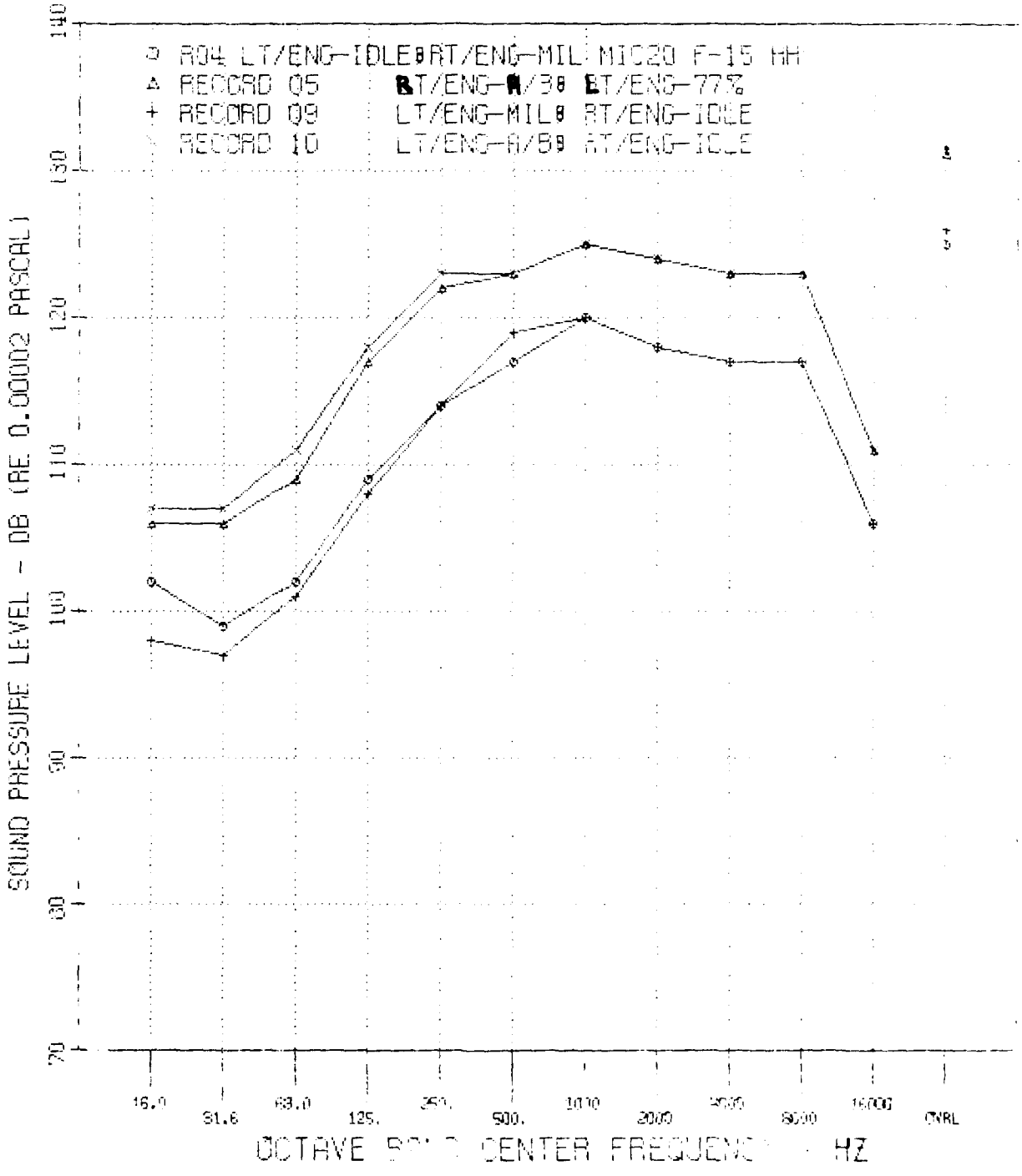


FIGURE B20 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 20.

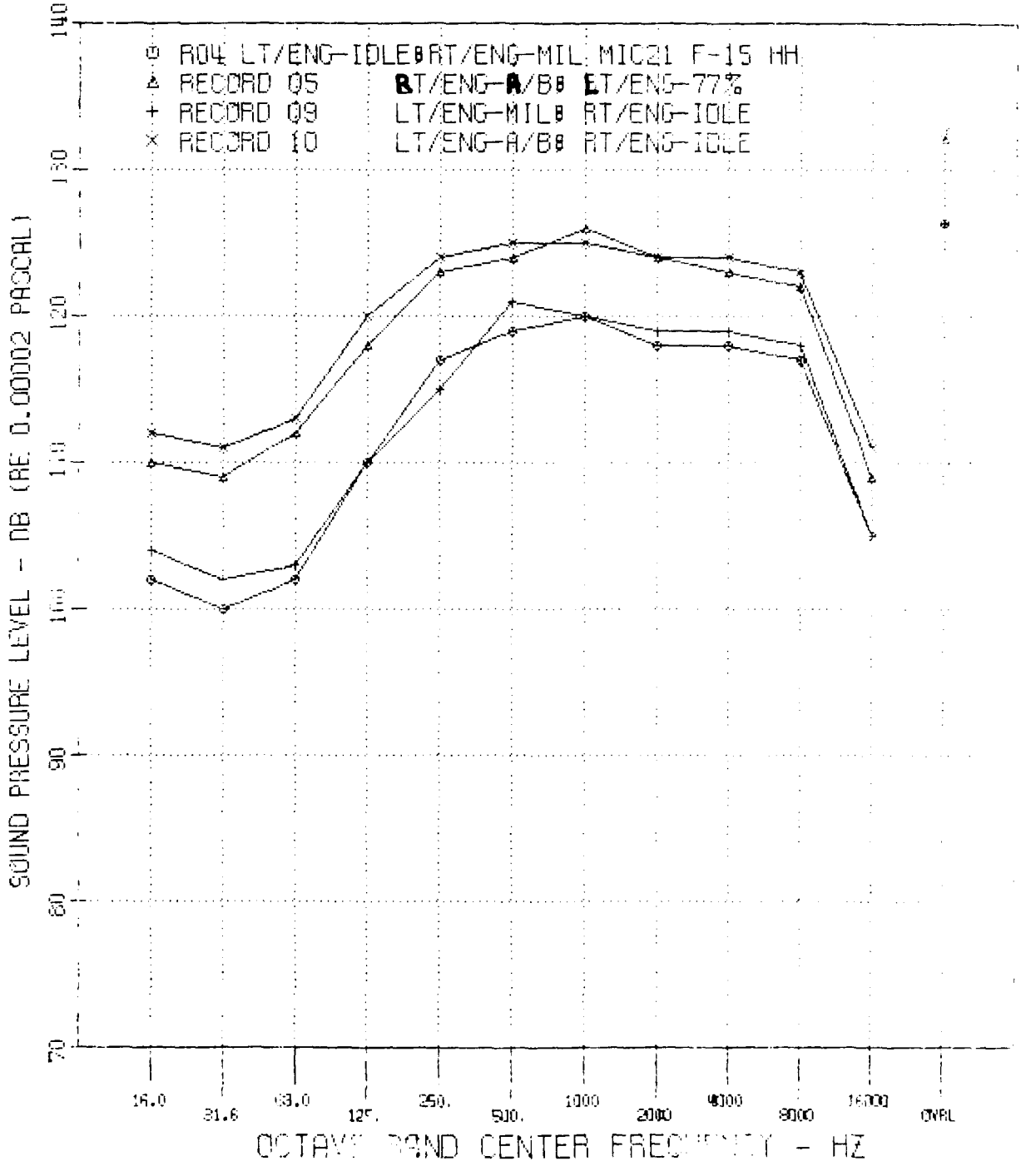


FIGURE B21 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 21.

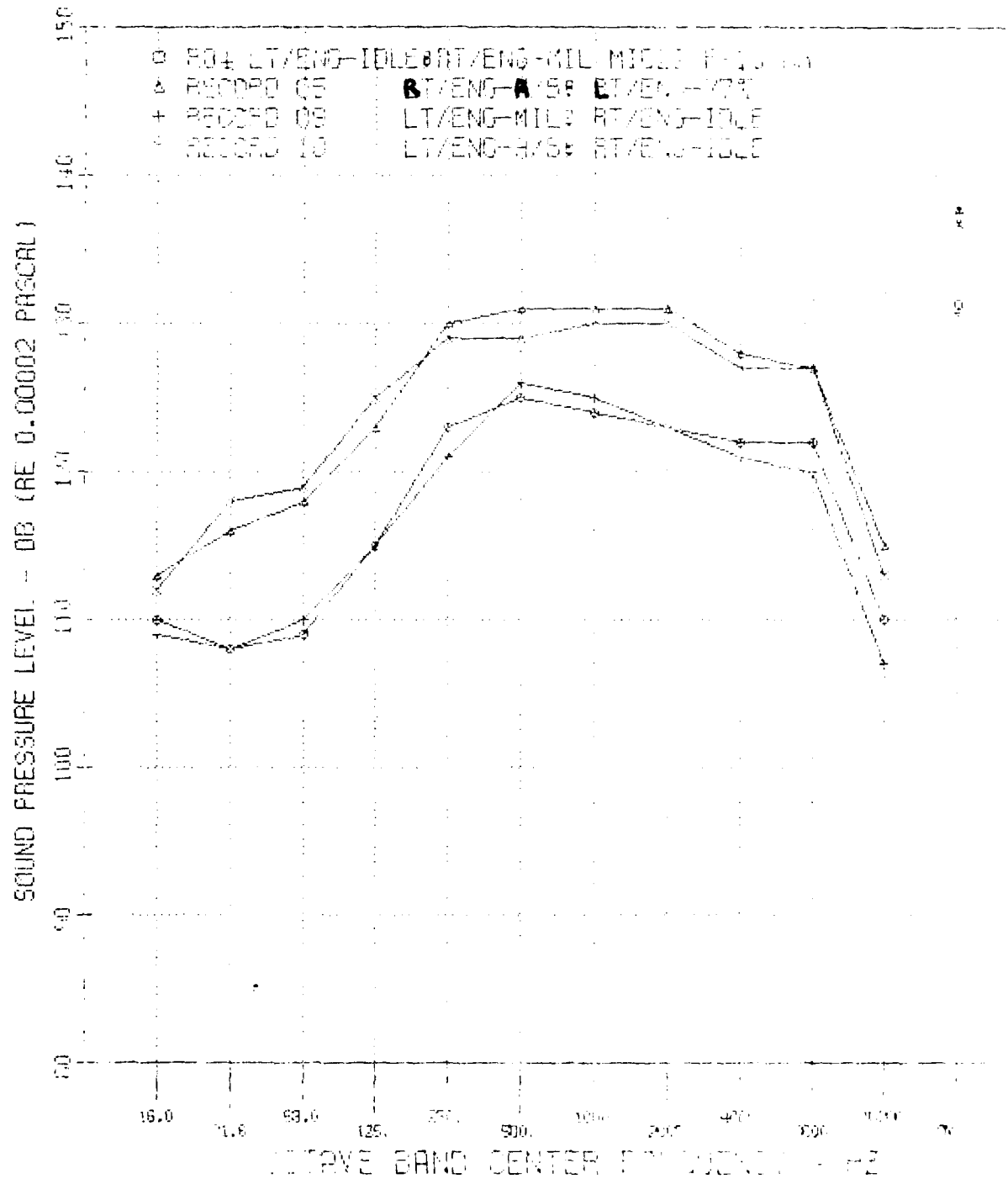


FIGURE B22 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Number 4, 5, 9, 10 - Microphone 22.

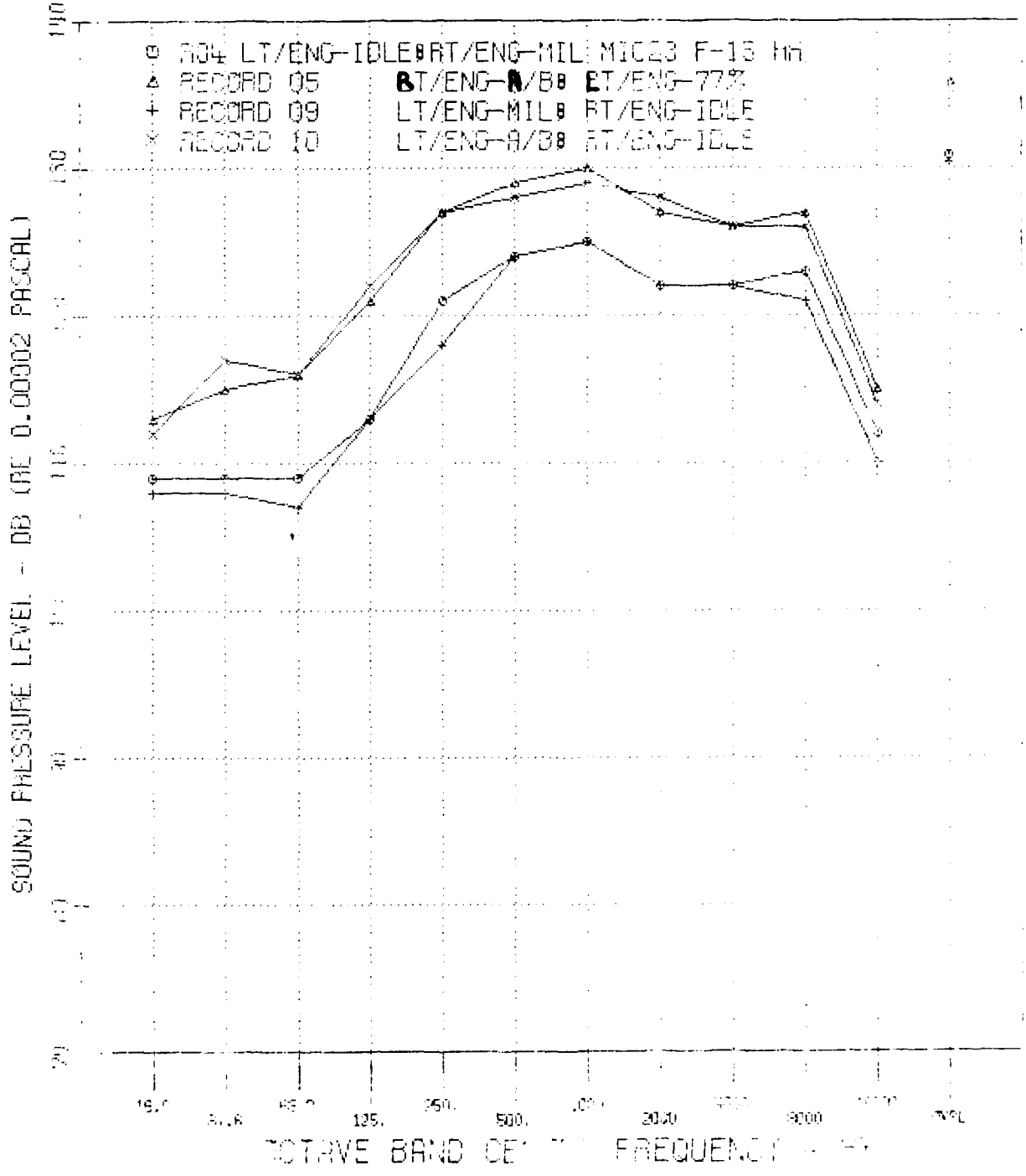


FIGURE B23 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 23.

GRAPH 24

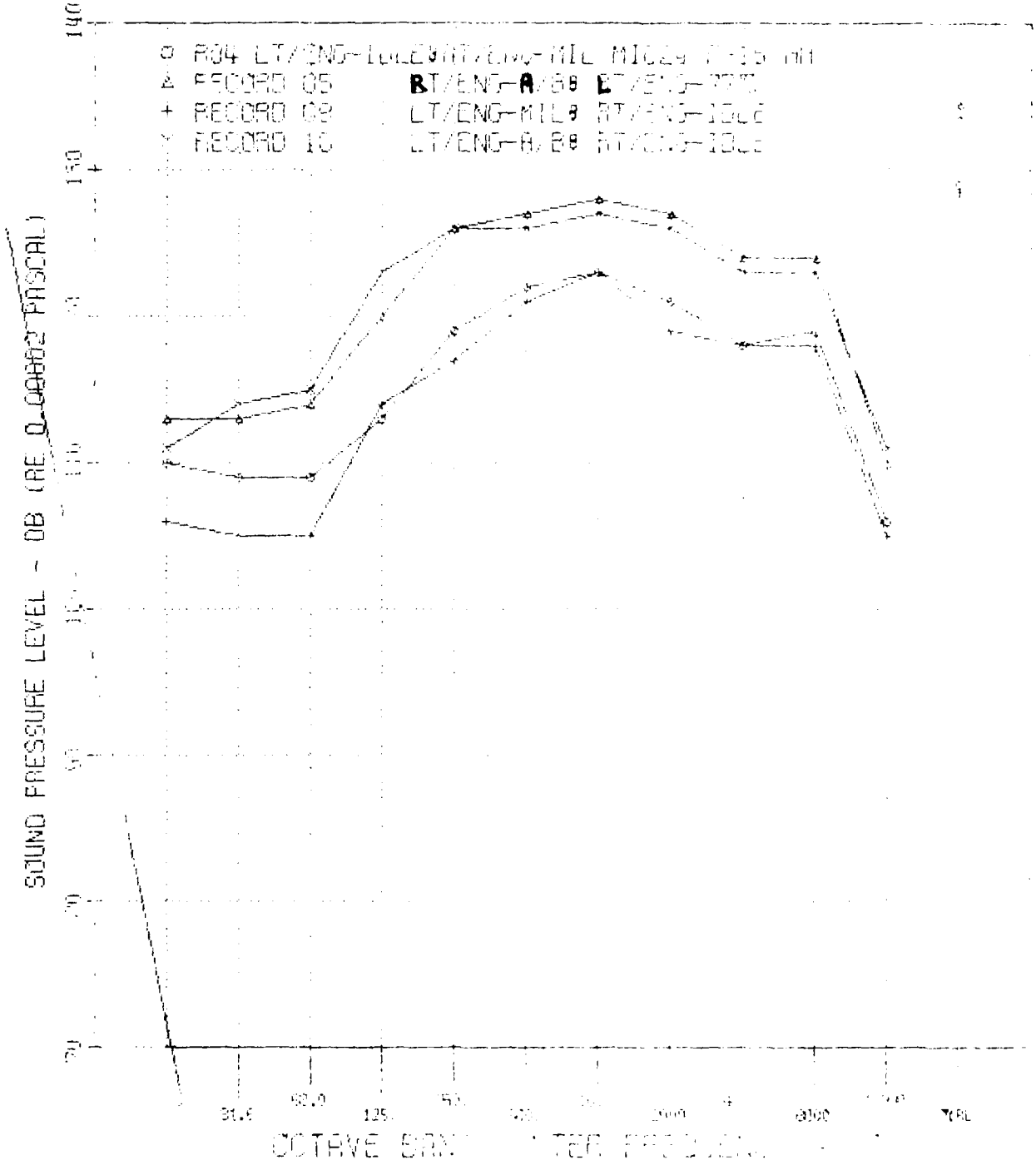


FIGURE B24 Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 24.

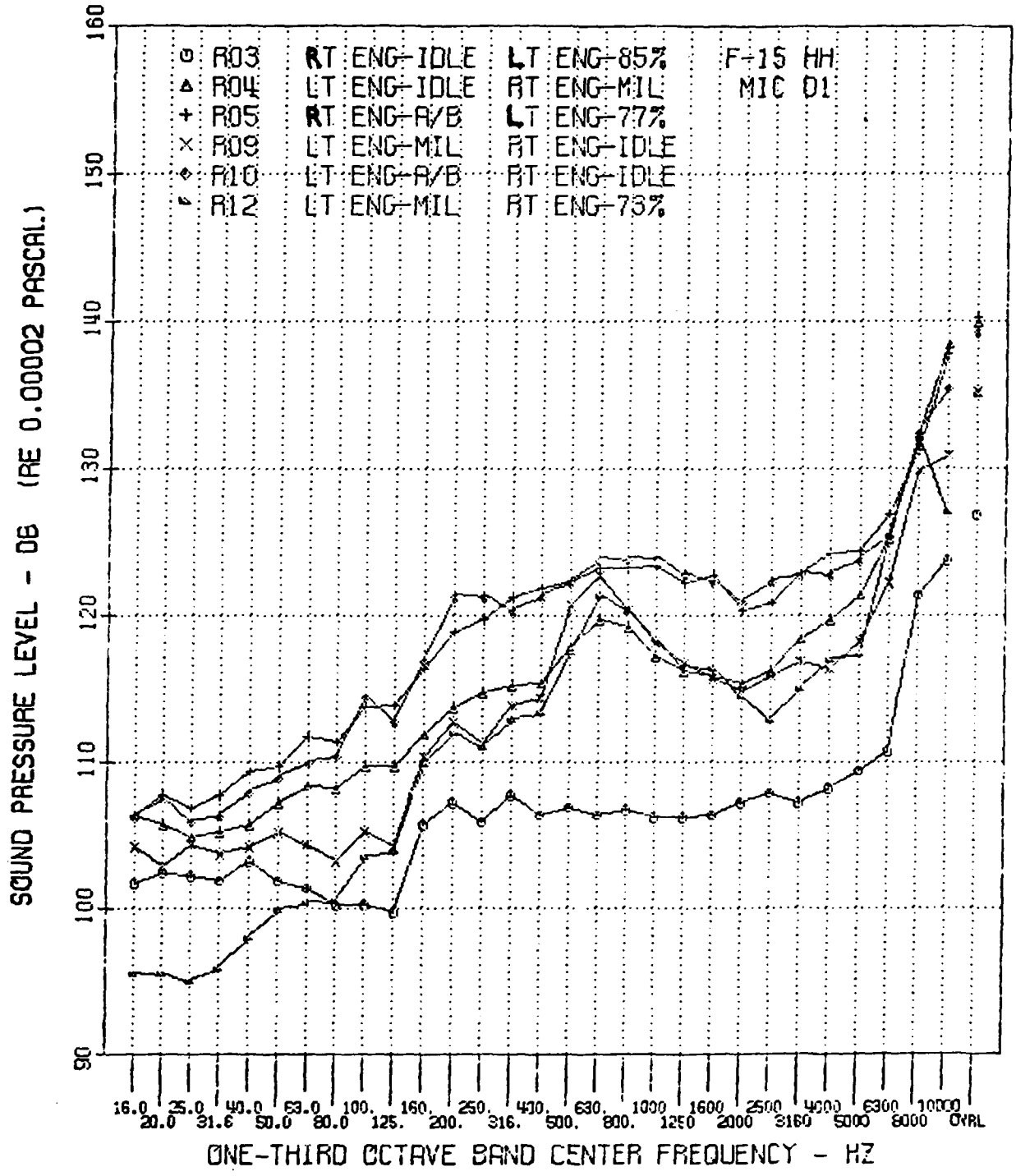


FIGURE B25 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphone 1.

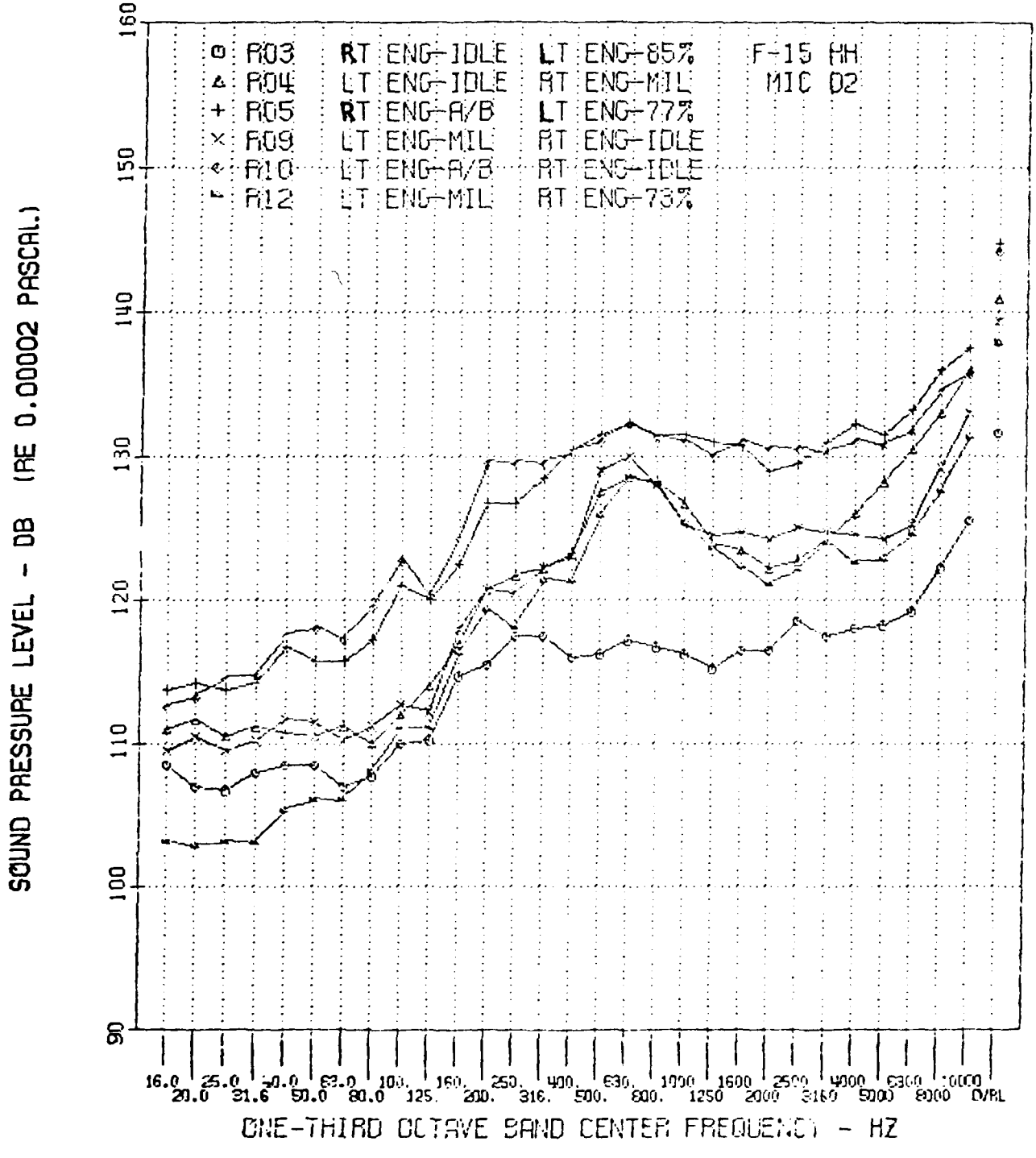


FIGURE B26 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphone 2.

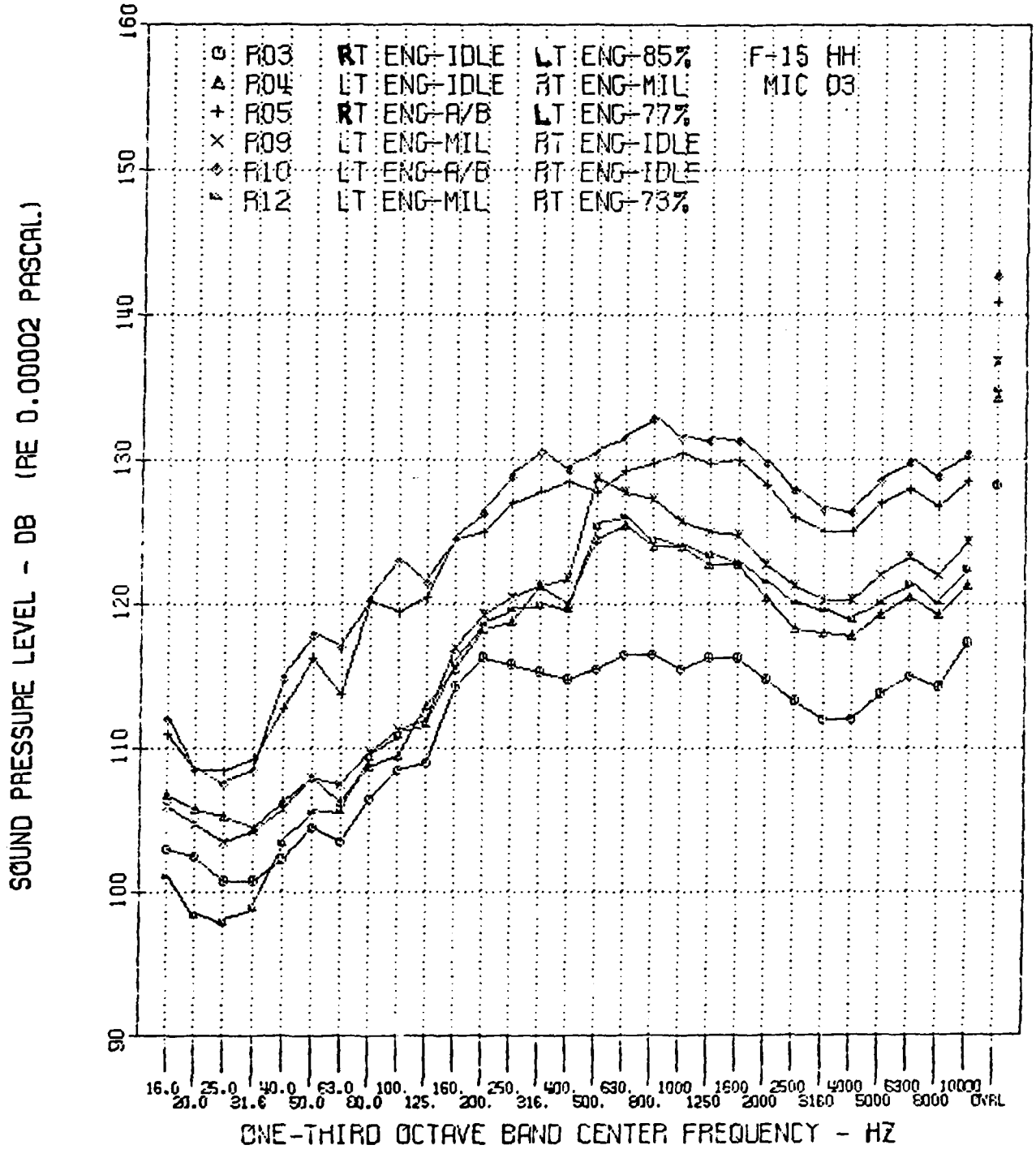


FIGURE B27 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphone 3.

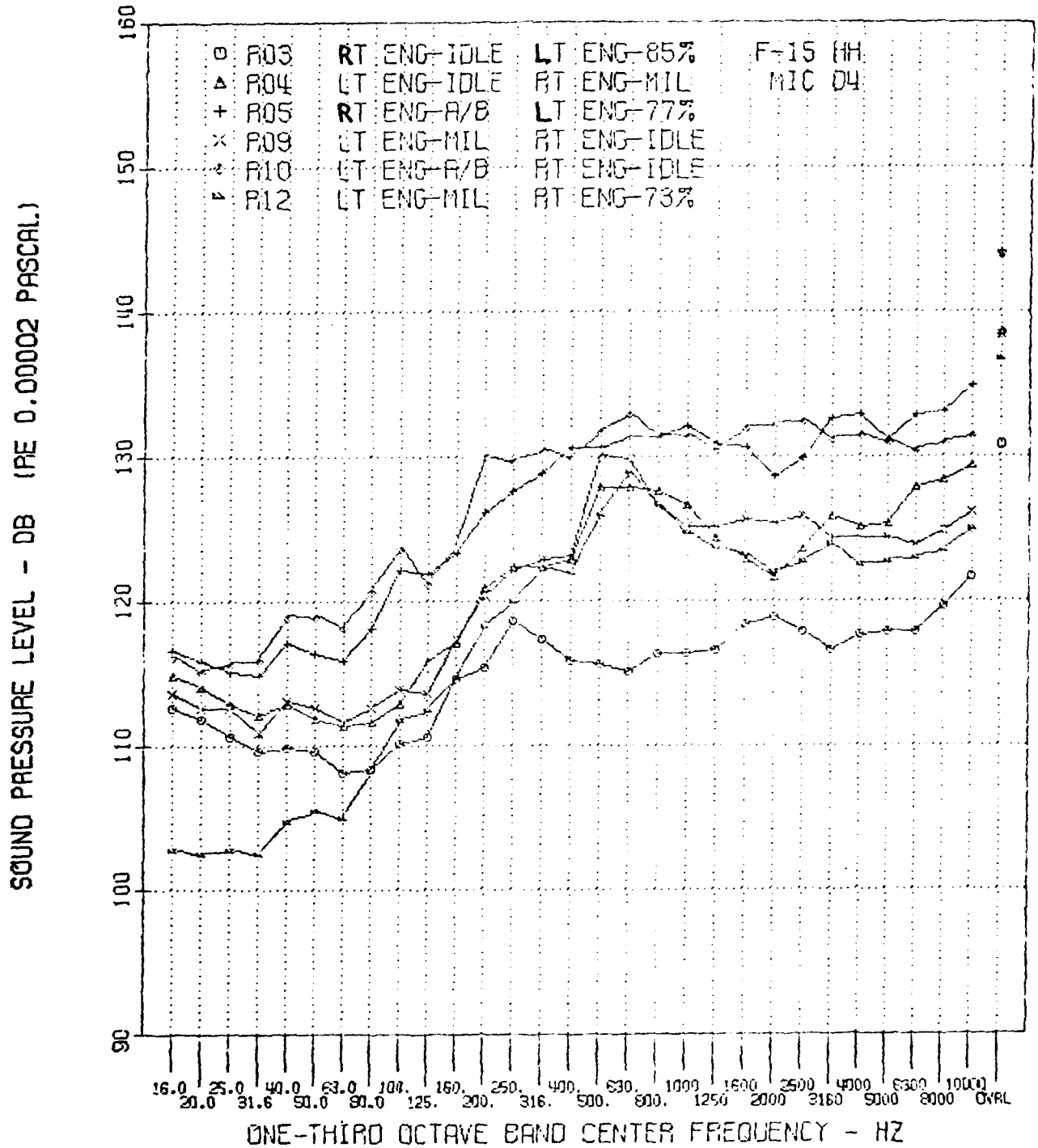


FIGURE B28 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphone 4.

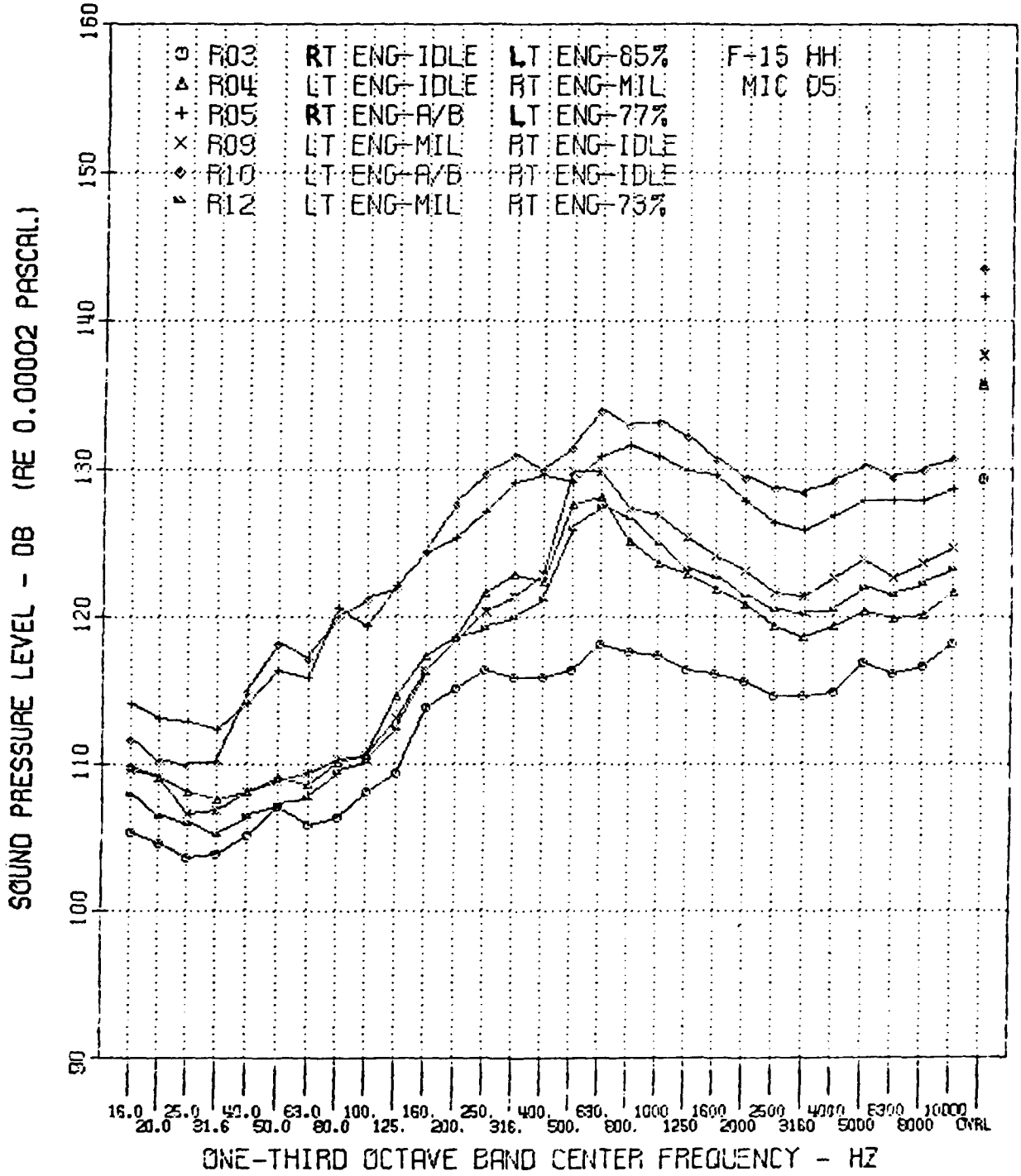


FIGURE B29 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphone 5.

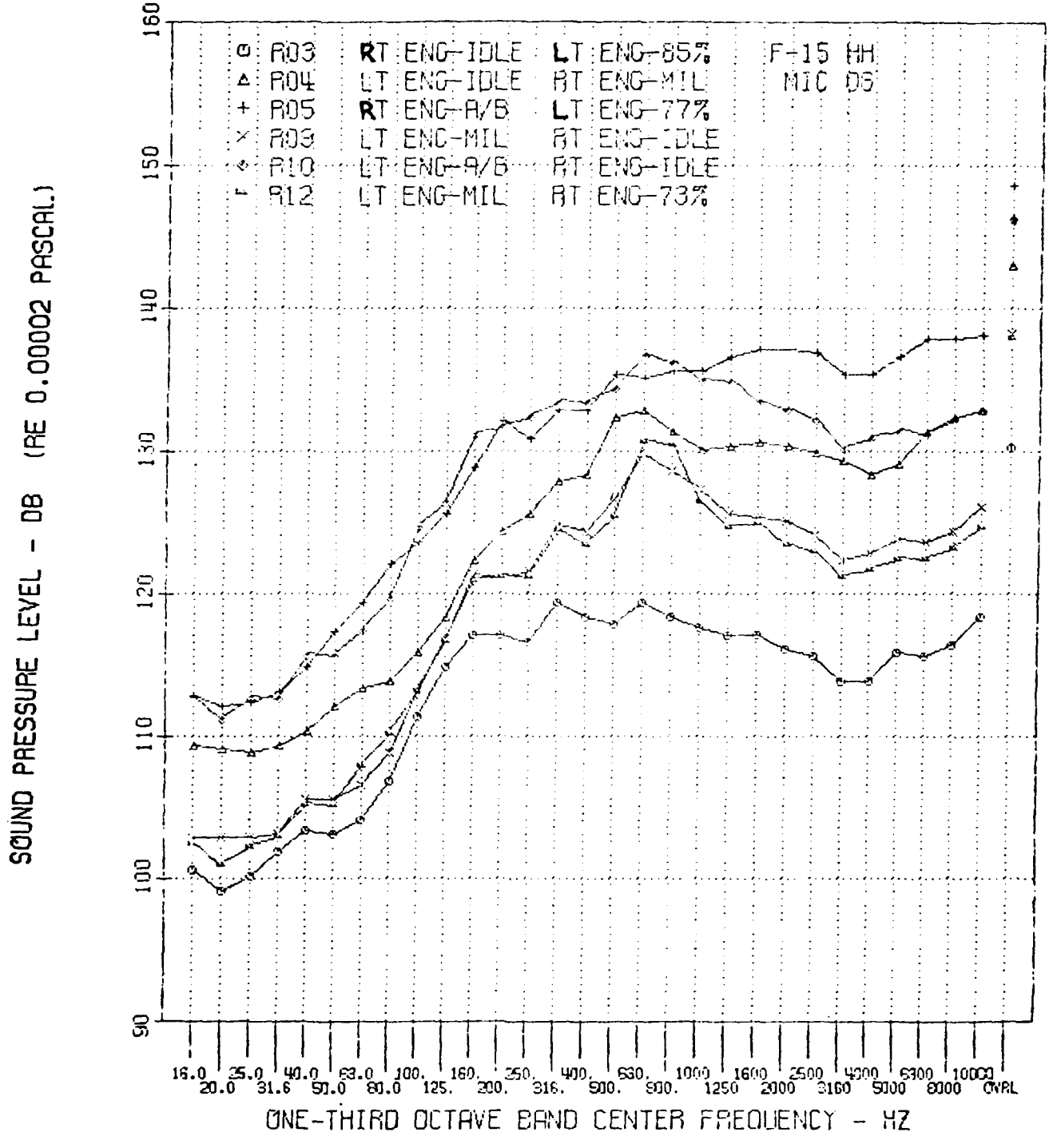


FIGURE B30 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphone 6.

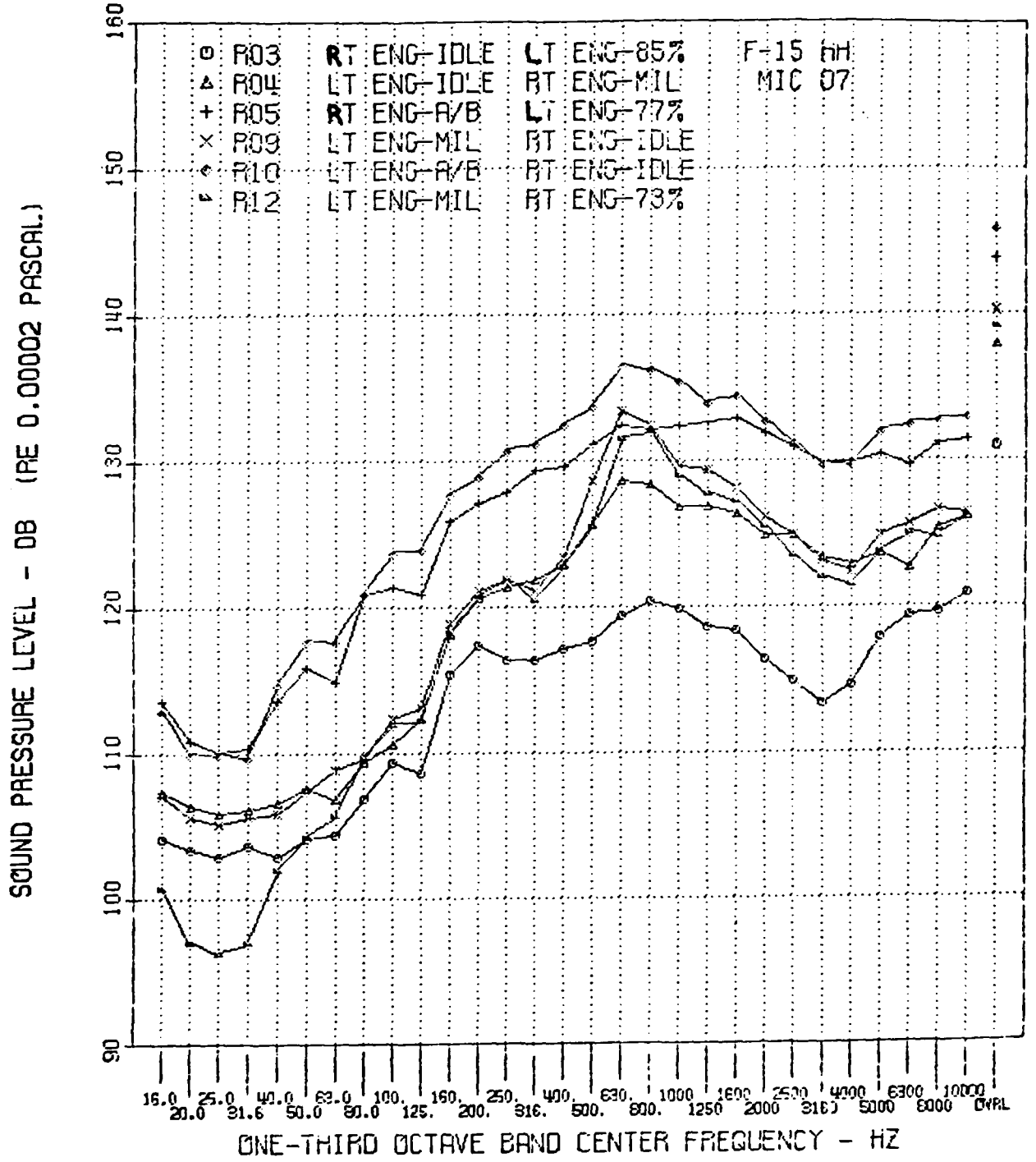


FIGURE B31 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphone 7.

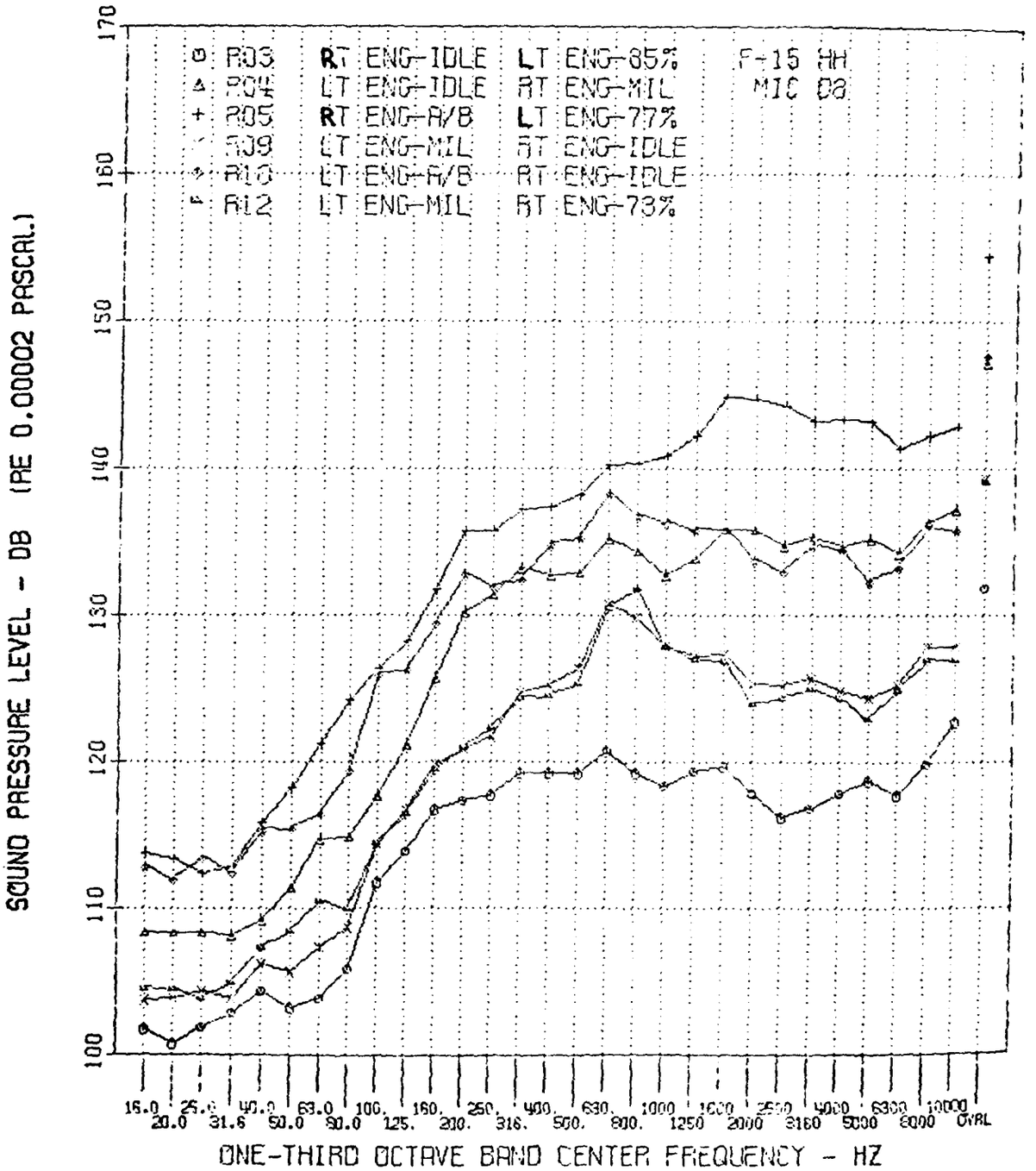


FIGURE B32 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphone 8.

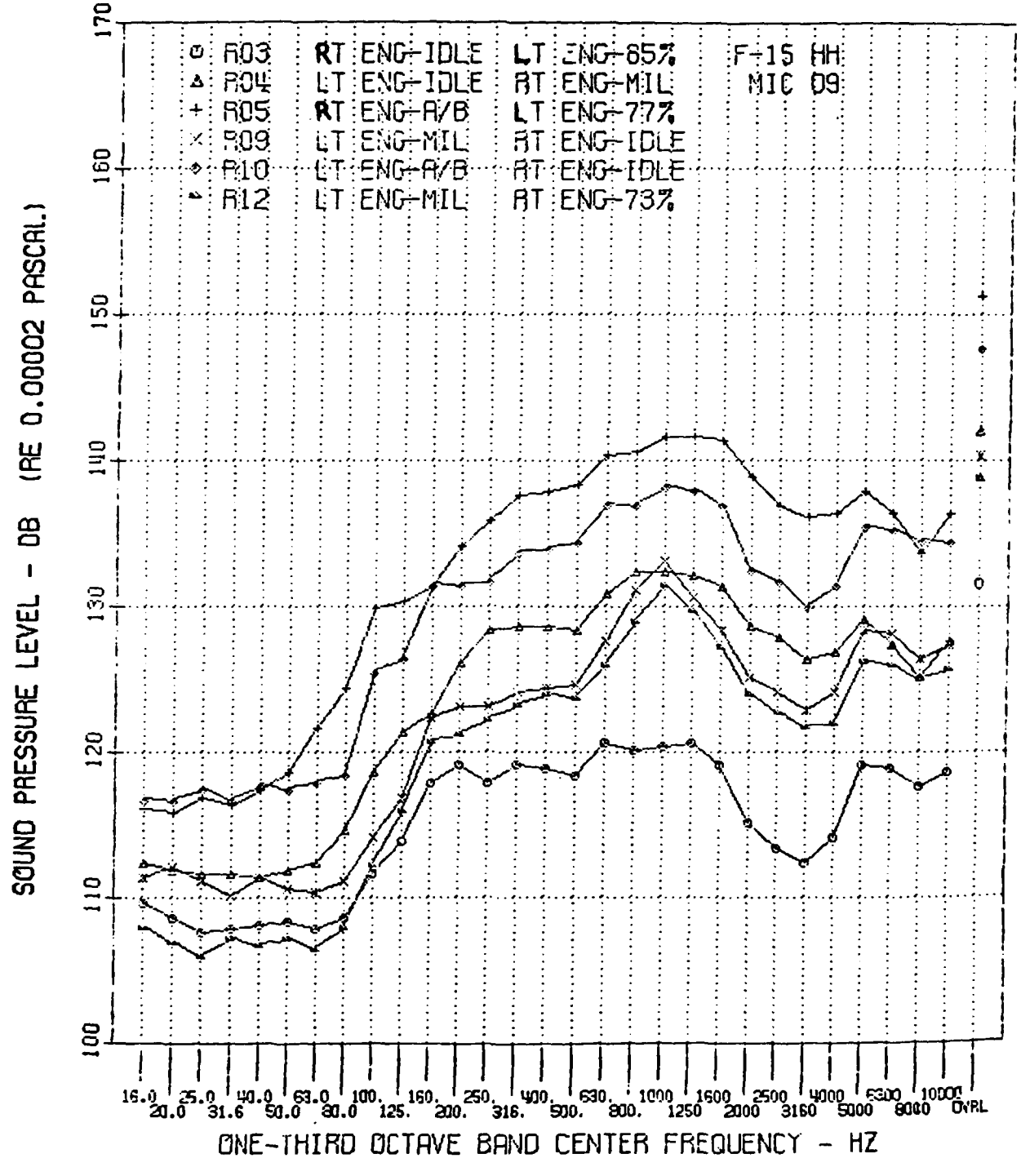


FIGURE B33 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphone 9.

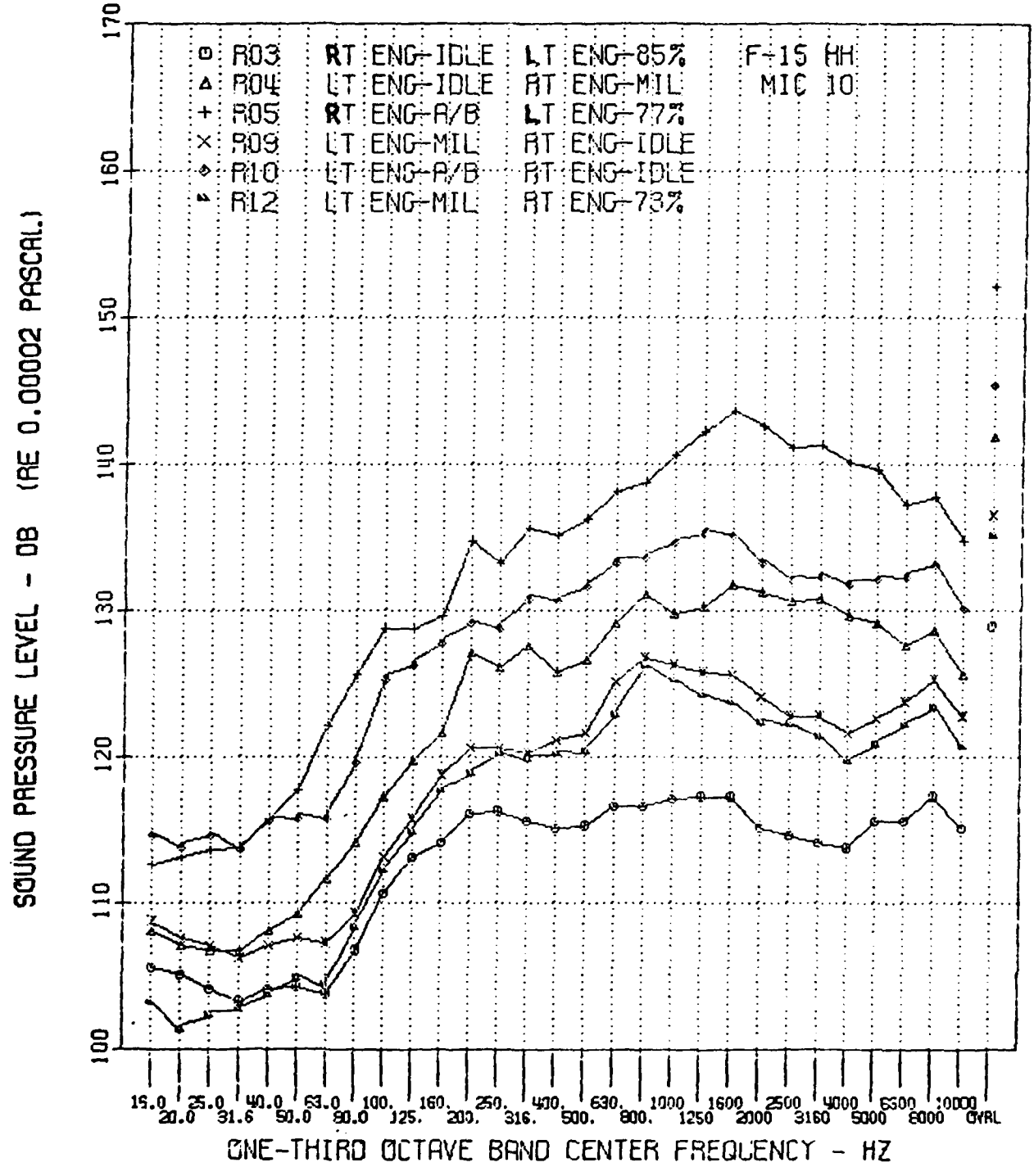


FIGURE B34 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphone 10.

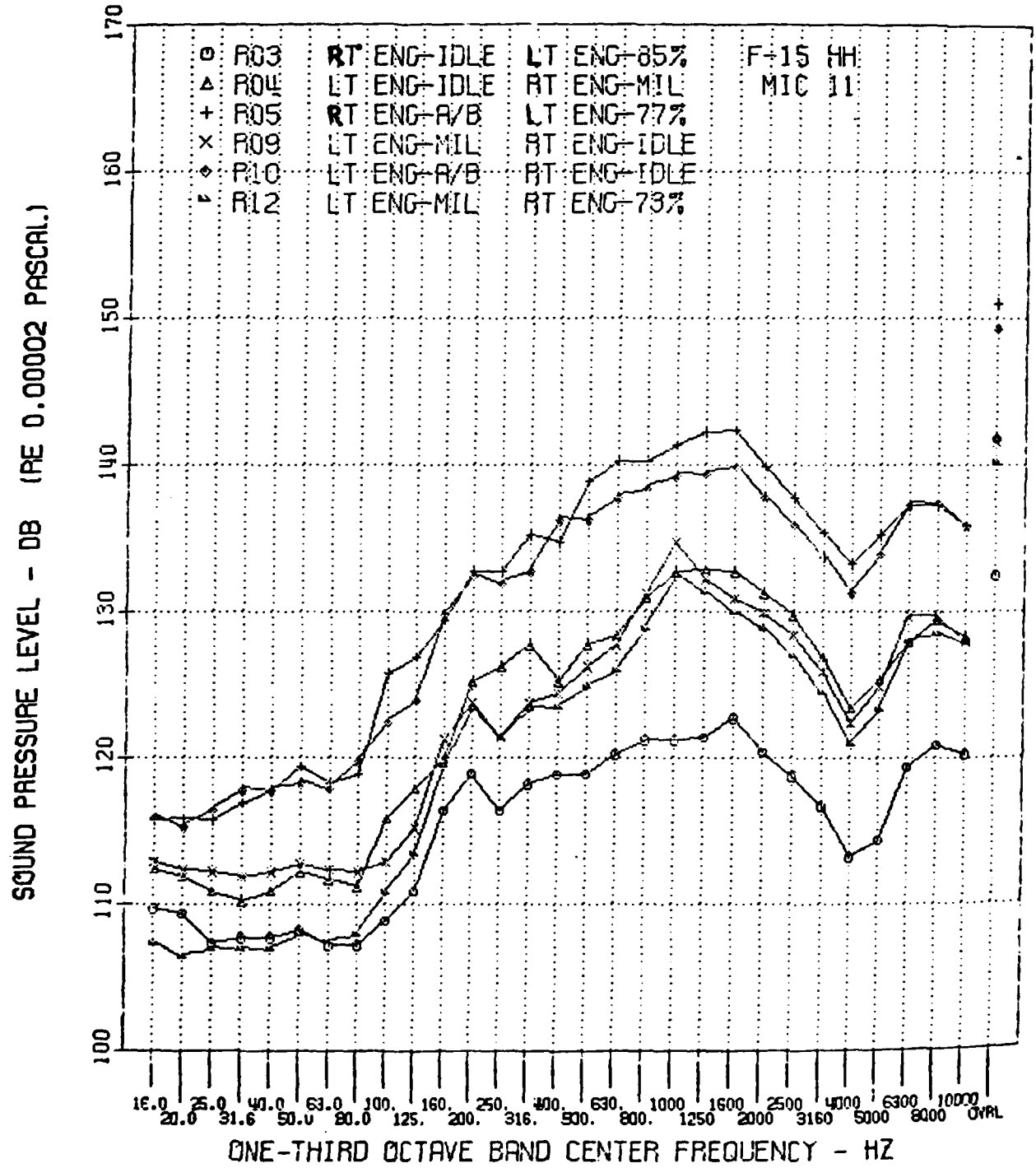


FIGURE B35 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphone 11.

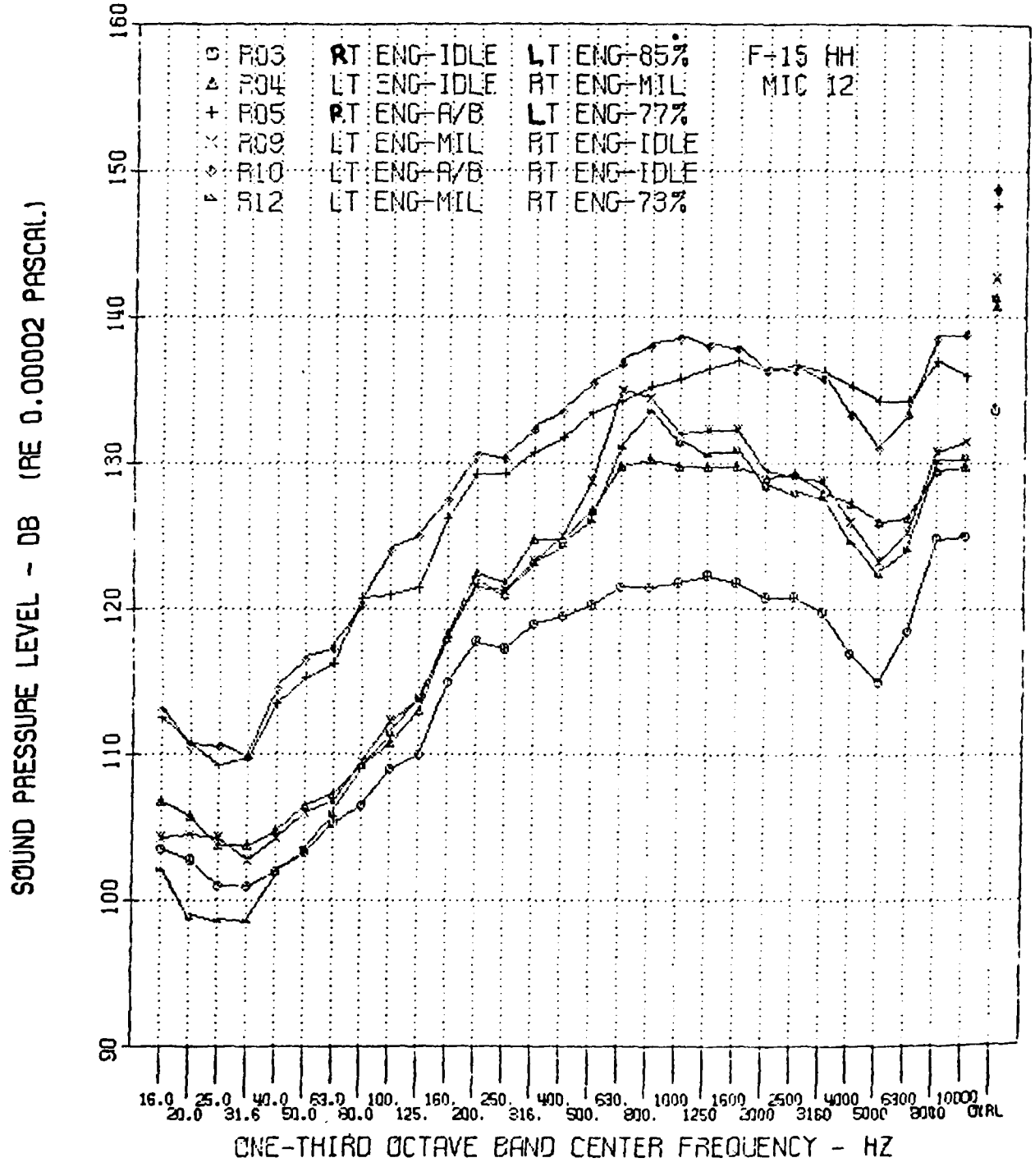


FIGURE B36 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphones 12.

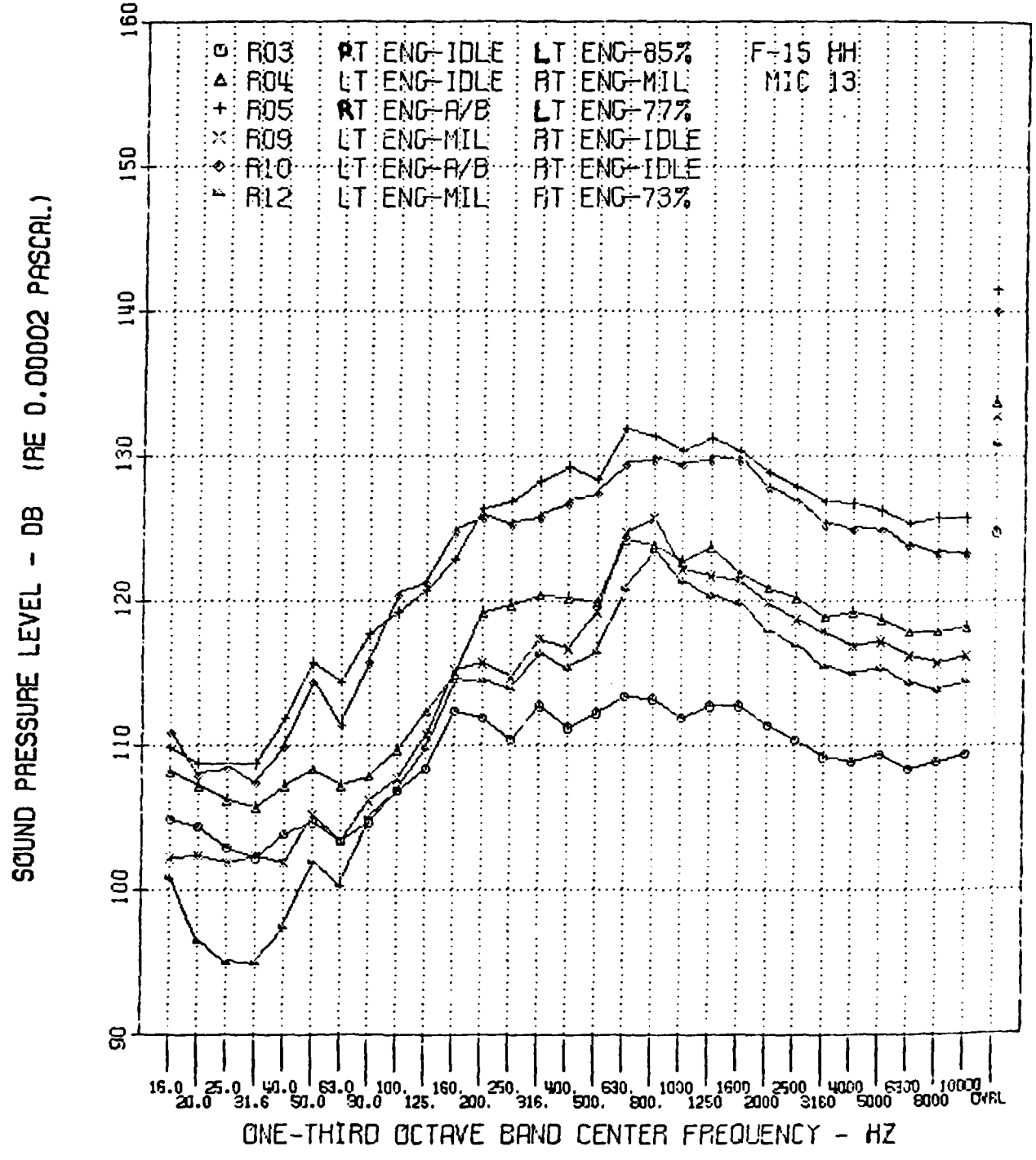


FIGURE B37 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphone 13.

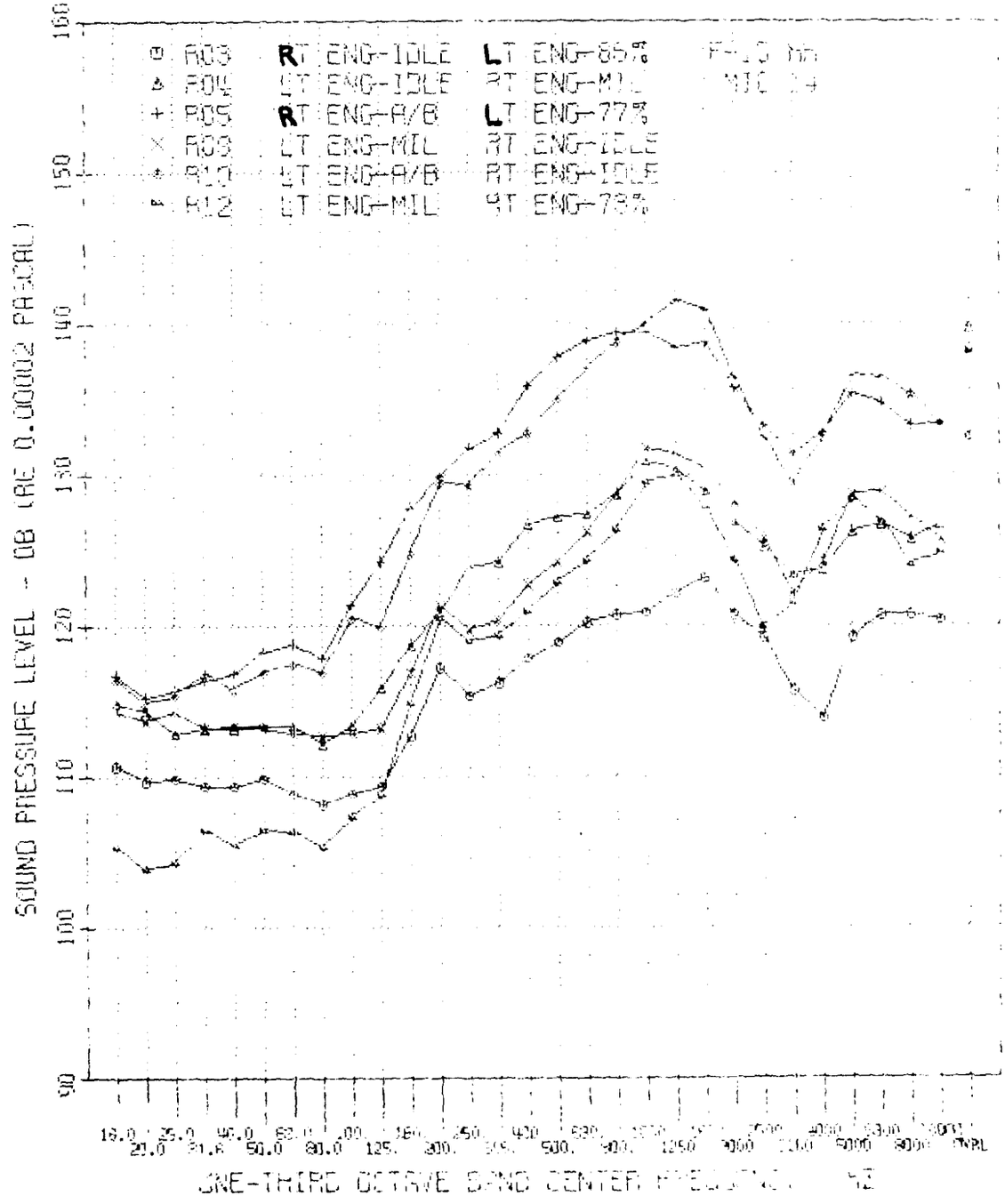


FIGURE B38 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphone 14.

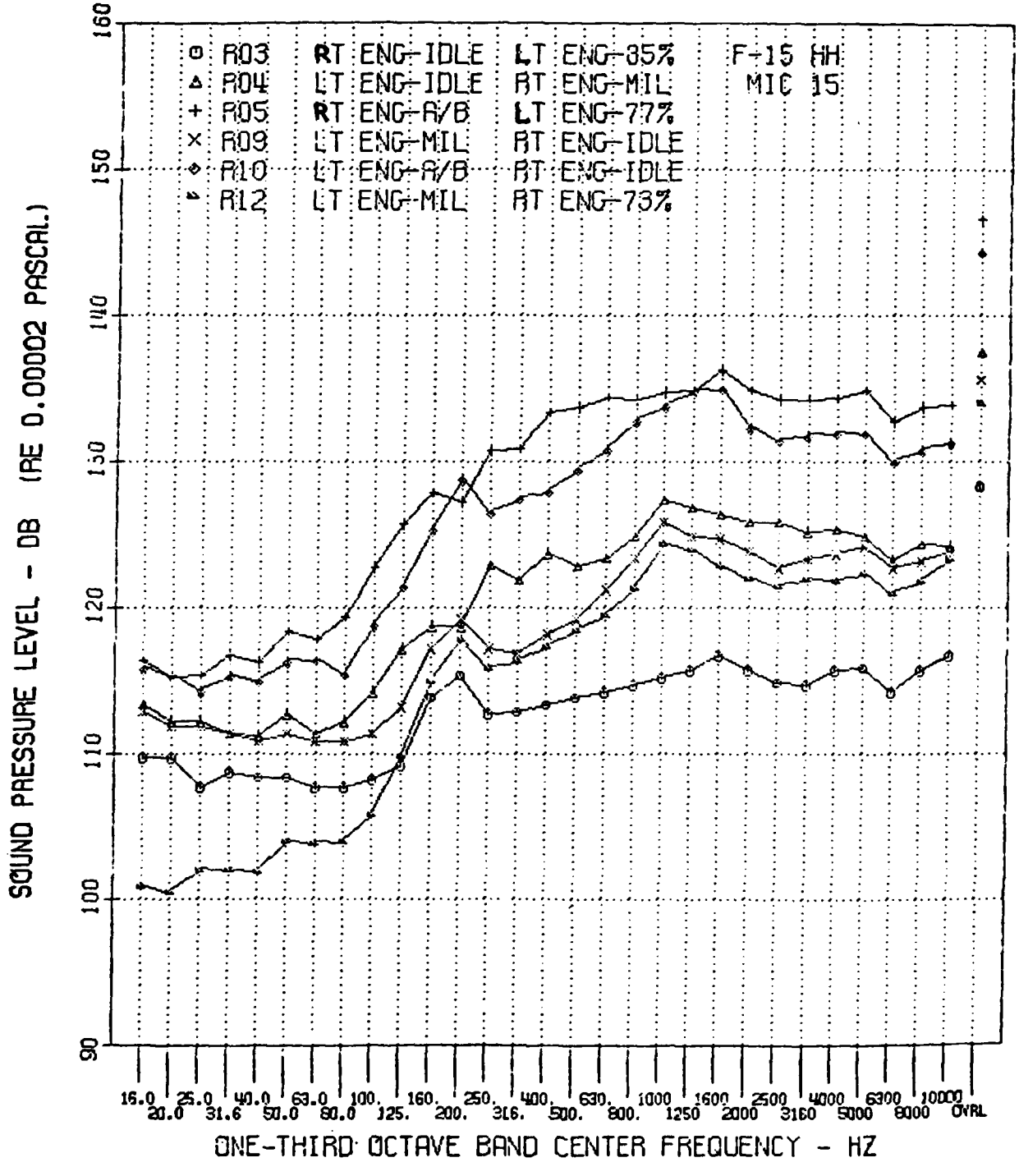


FIGURE B39 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphone 15.

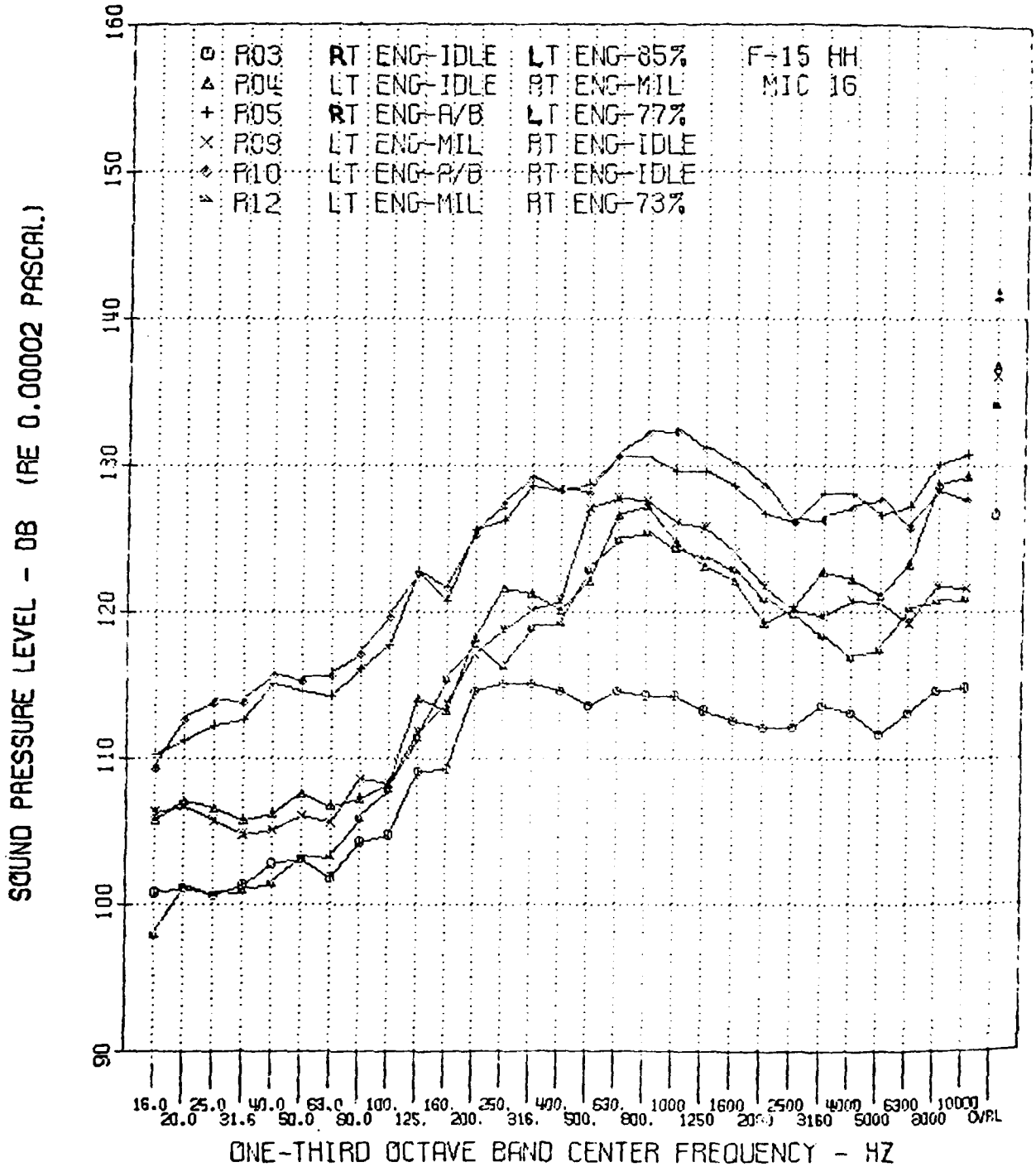


FIGURE B40 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphone 16.

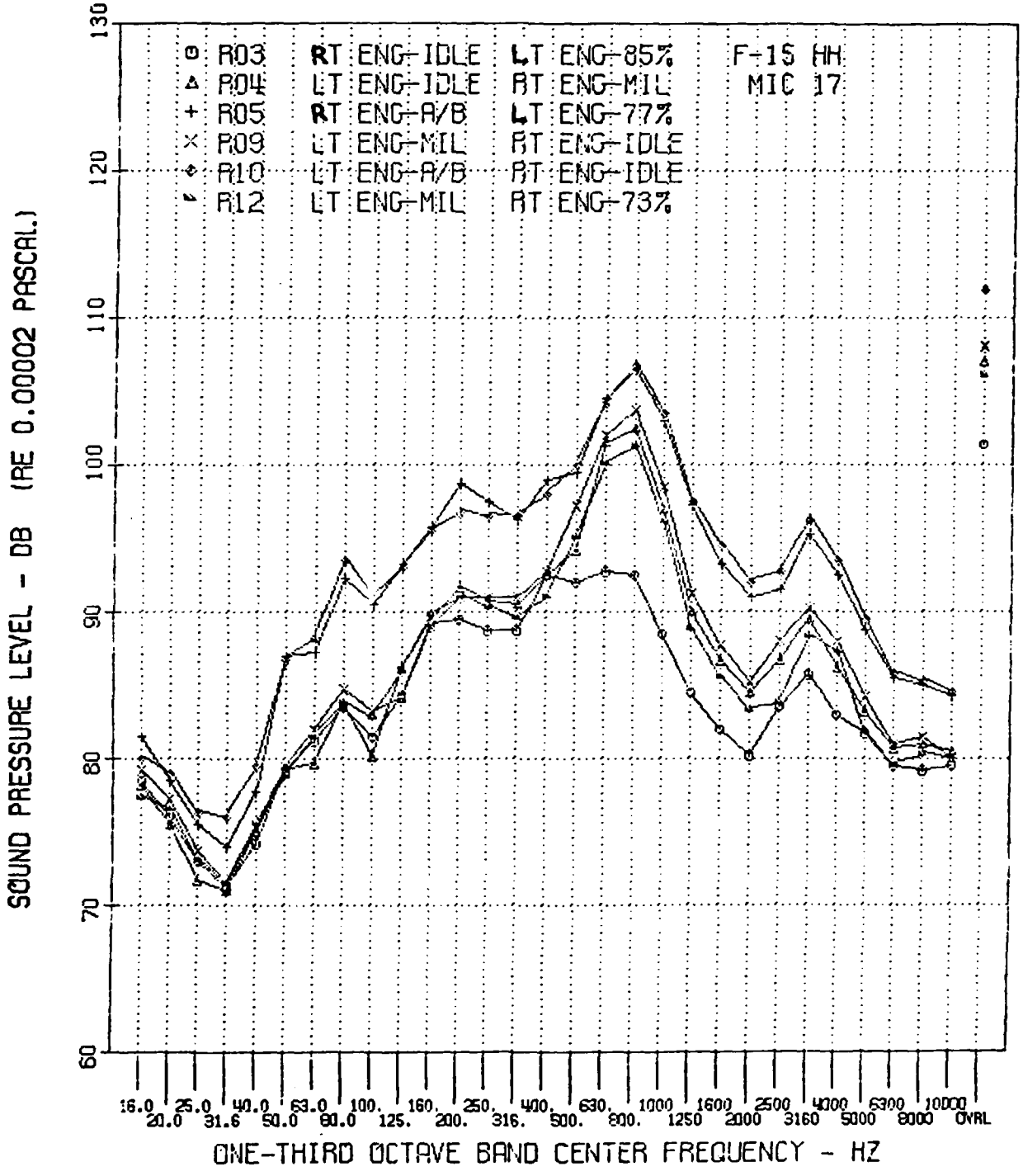


FIGURE B41 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphone 17.

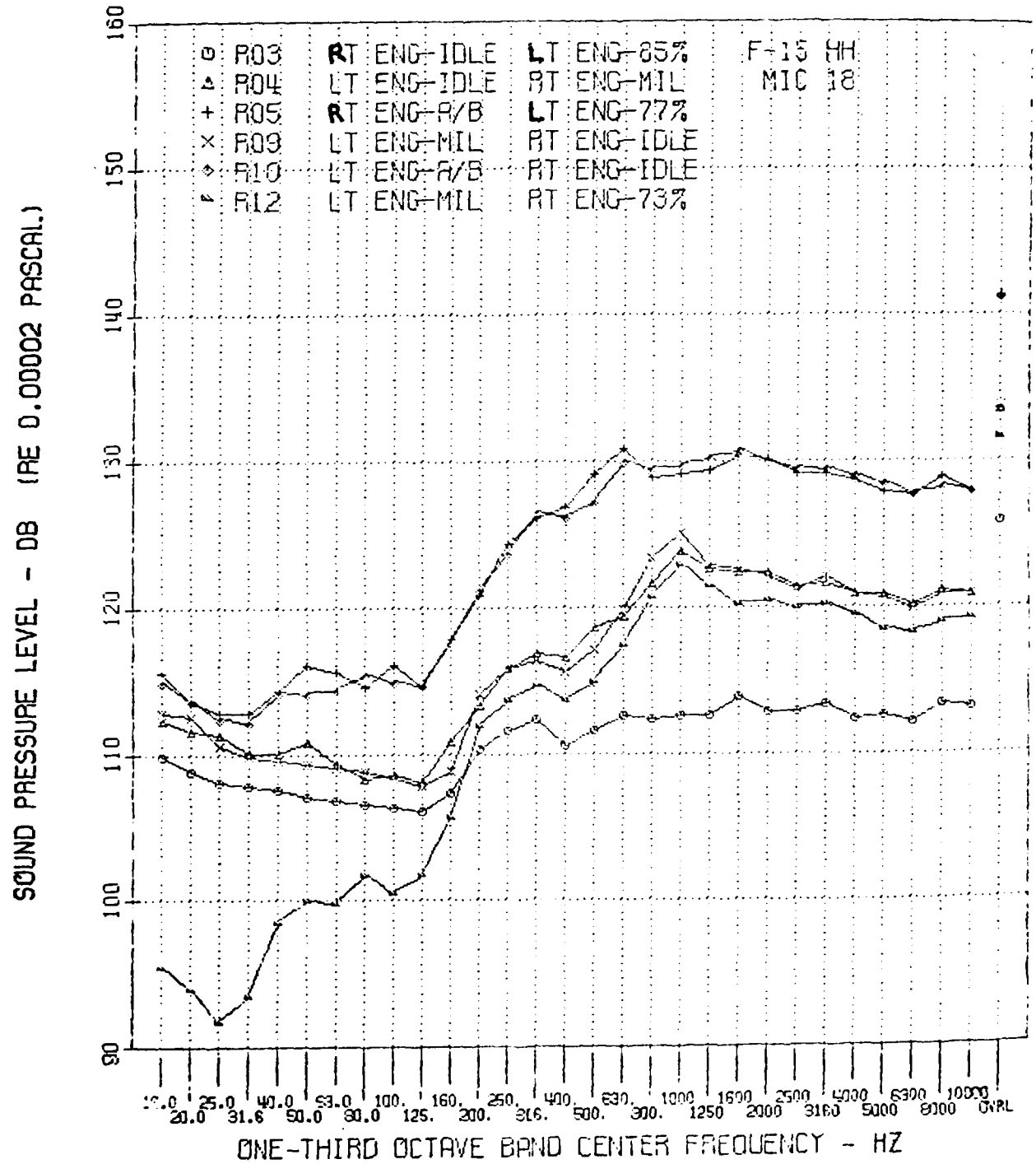


FIGURE B42 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphone 18.

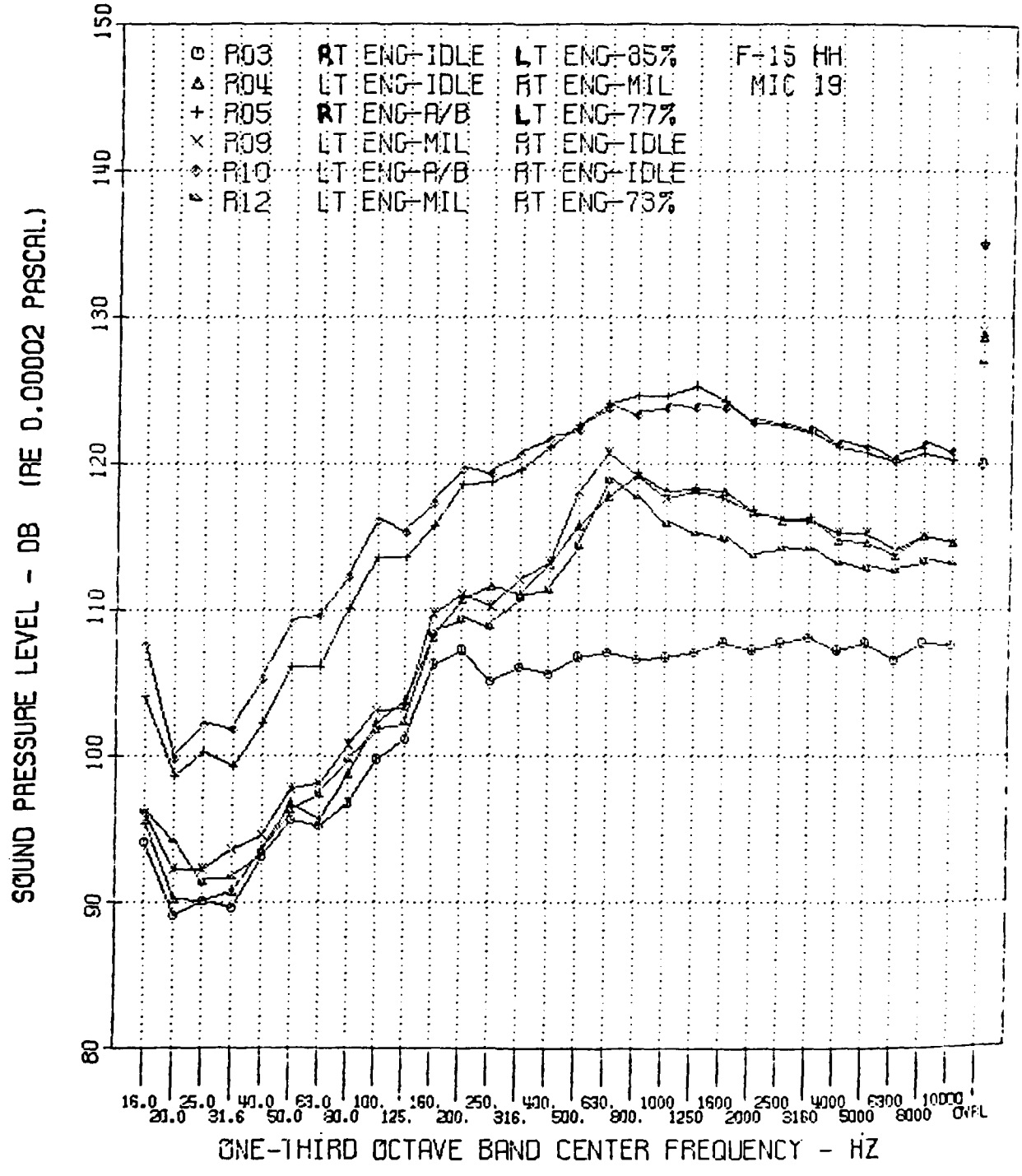


FIGURE B43 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphone 19.

AD-A109 828 AIR FORCE WRIGHT AERONAUTICAL LABS WRIGHT-PATTERSON AFB OH F/G 20/1
ACOUSTIC MEASUREMENTS OF F-15 AIRCRAFT OPERATING IN HUSH HOUSE,--ETC(U)
SEP 81 V R MILLER, G A PLZAK, J M CHINN

UNCLASSIFIED AFWAL-TM-81-82-FIBE NL

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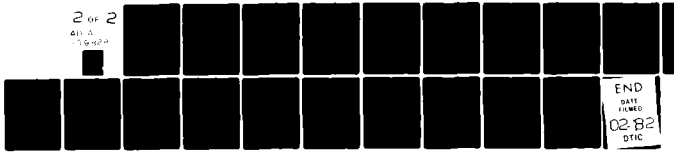

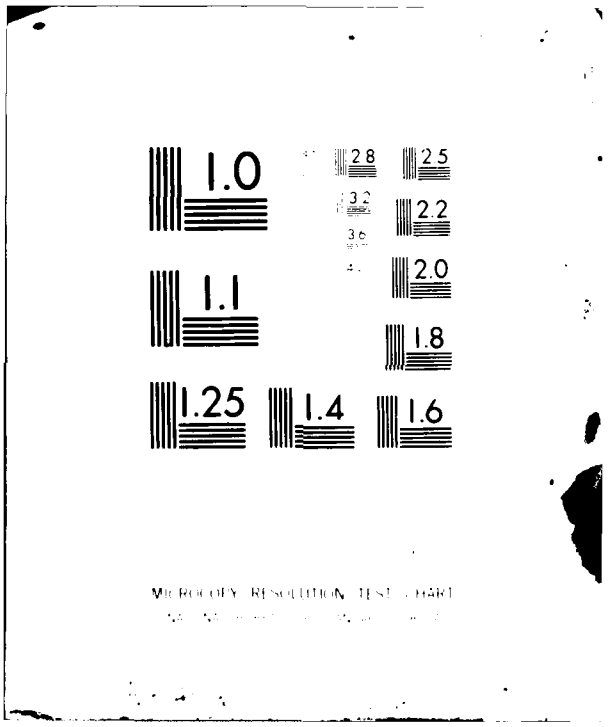
1.0
2.8
2.5
3.2
2.2
3.6
2.0
1.1
1.8
1.25
1.4
1.6
MICROCOPY RESOLUTION TEST CHART

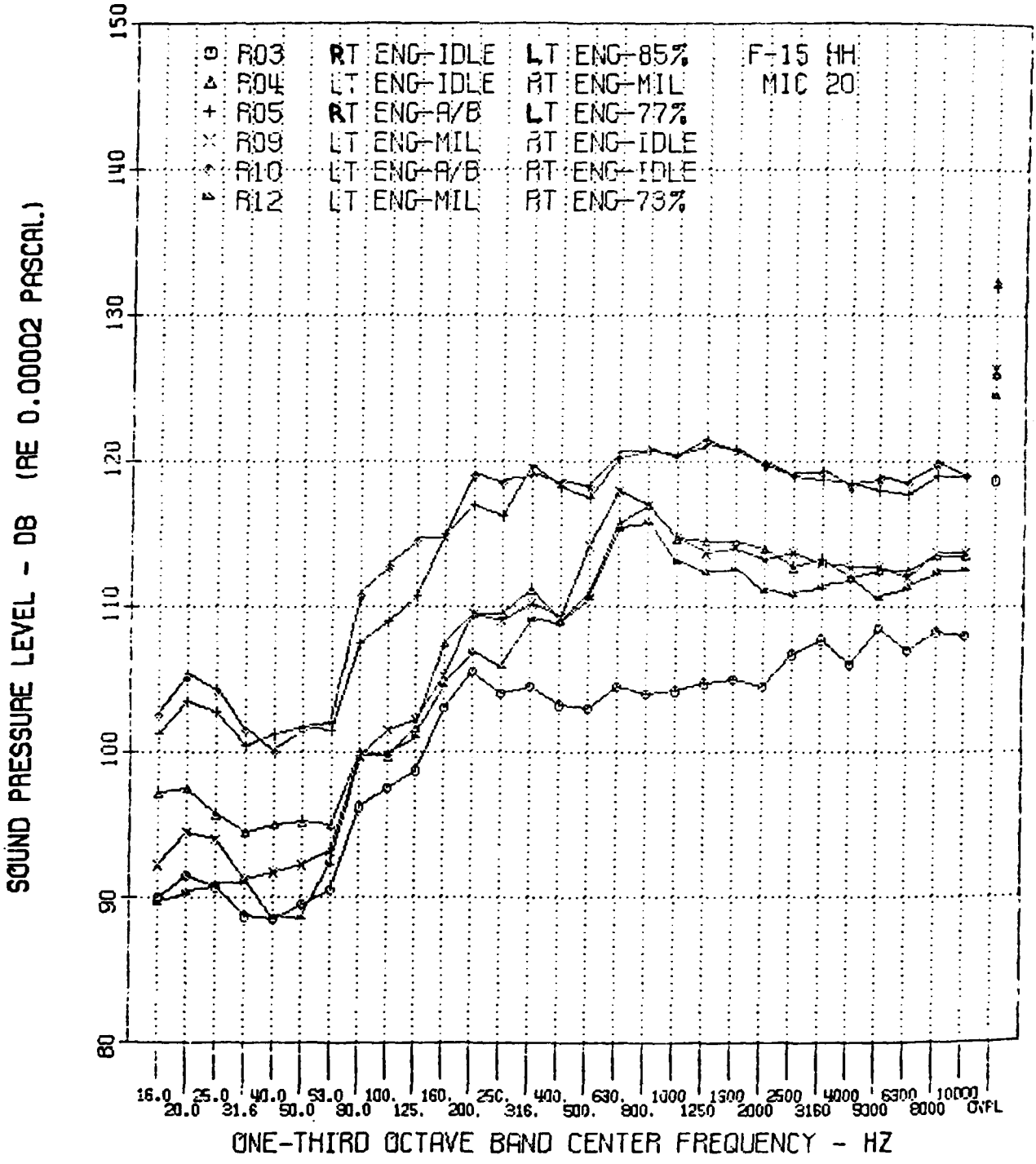

FIGURE B44 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphone 20.

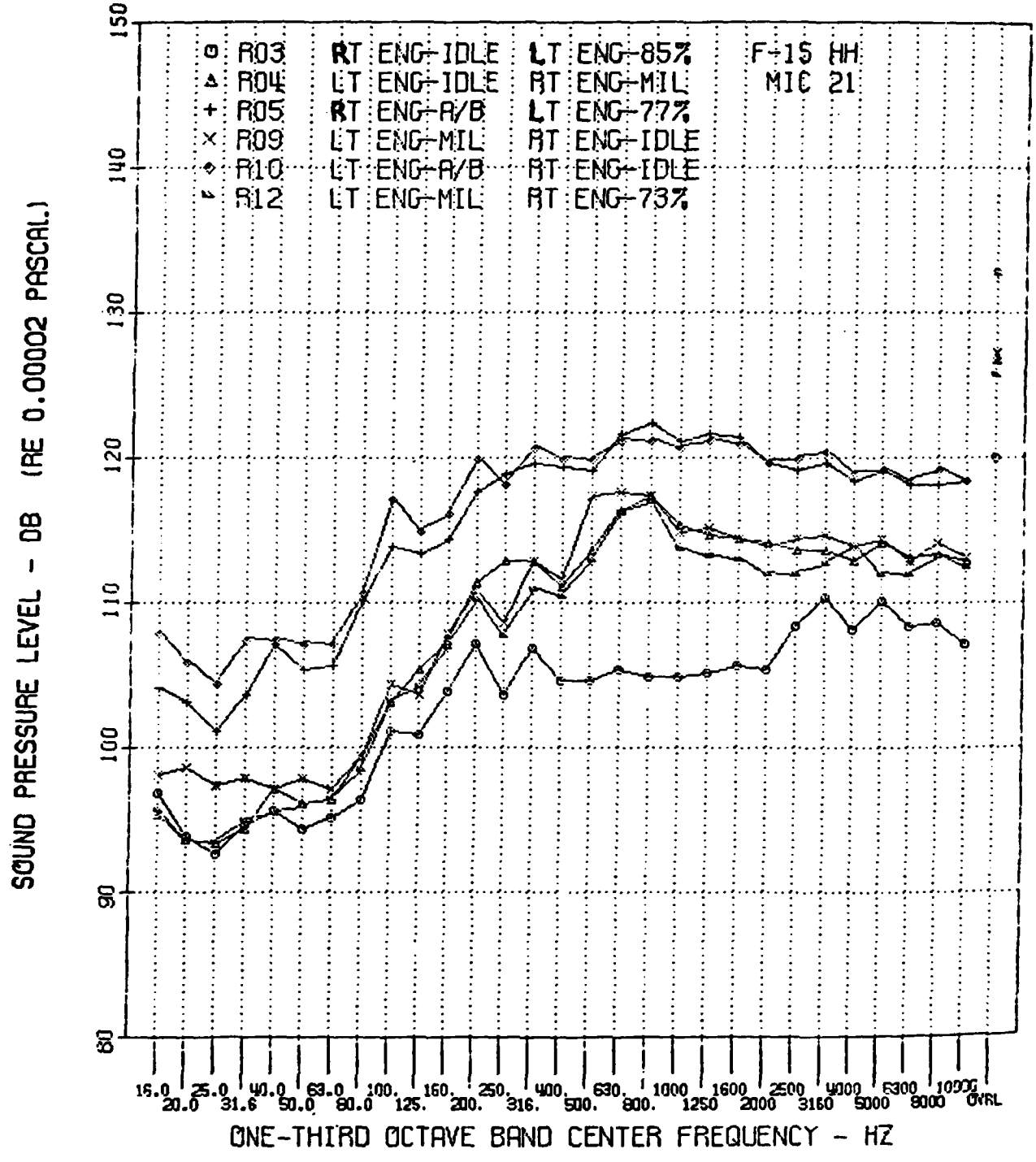

FIGURE B45 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphone 21.

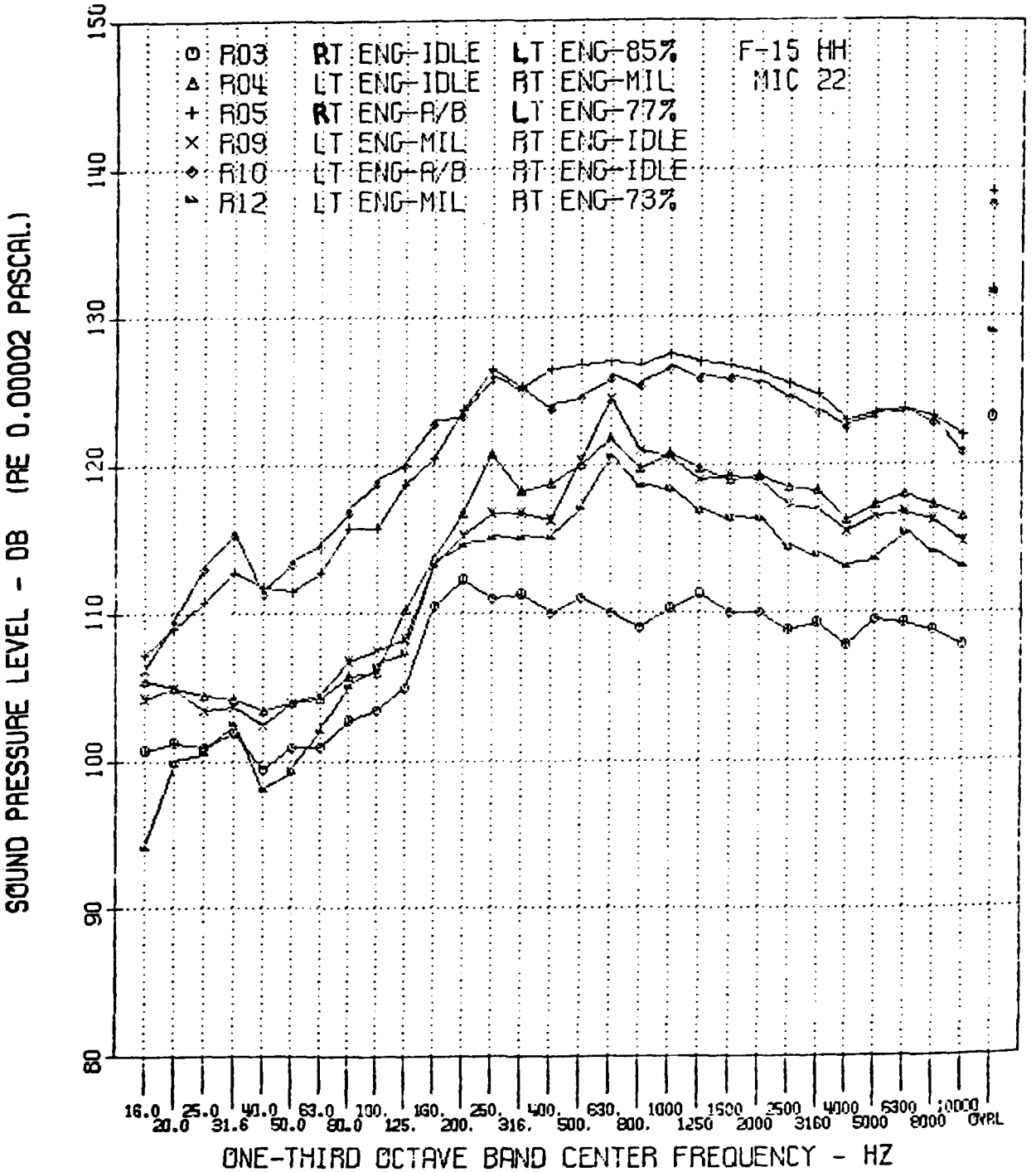

FIGURE B46 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphone 22.

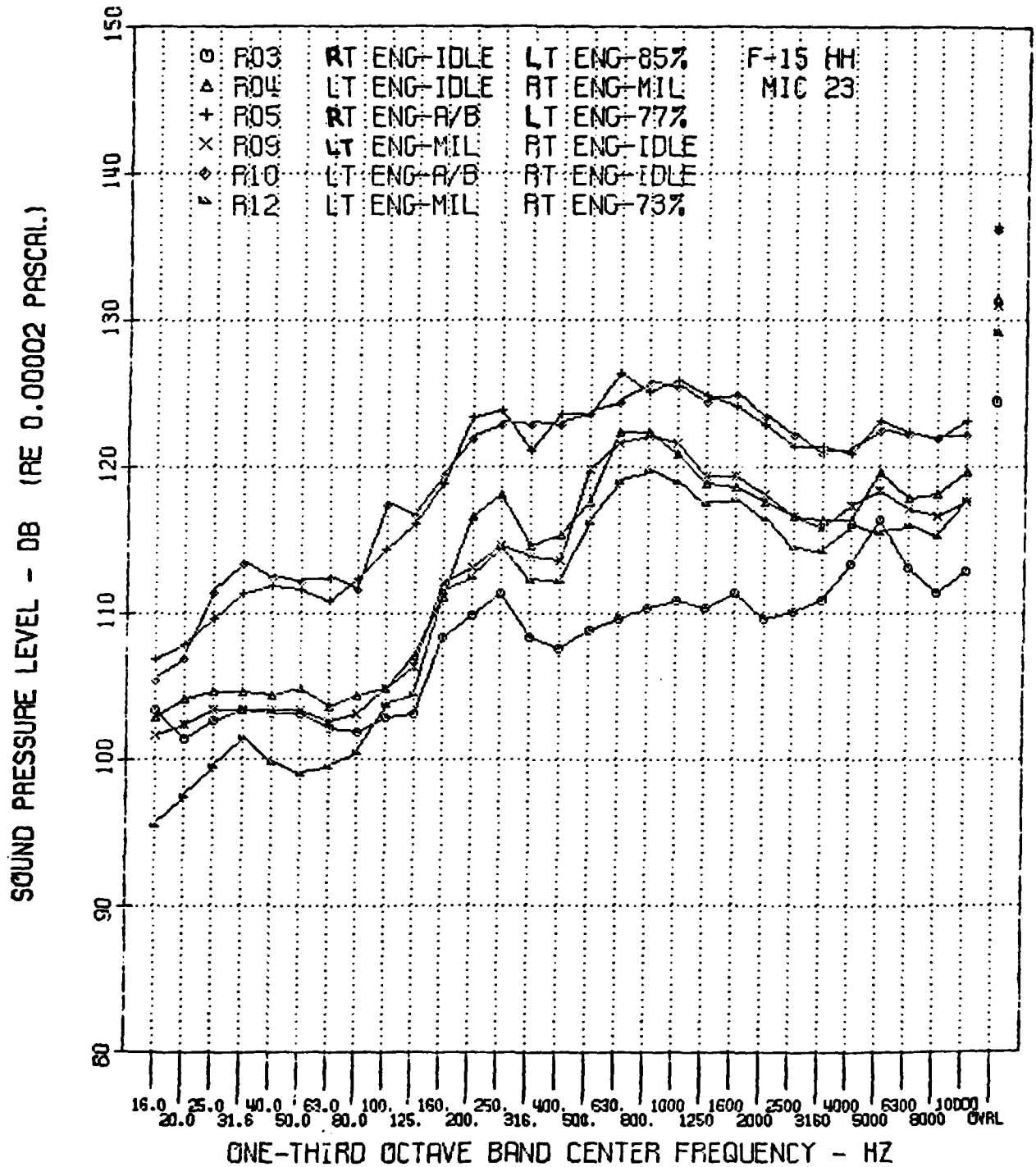

FIGURE B47 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphone 23.

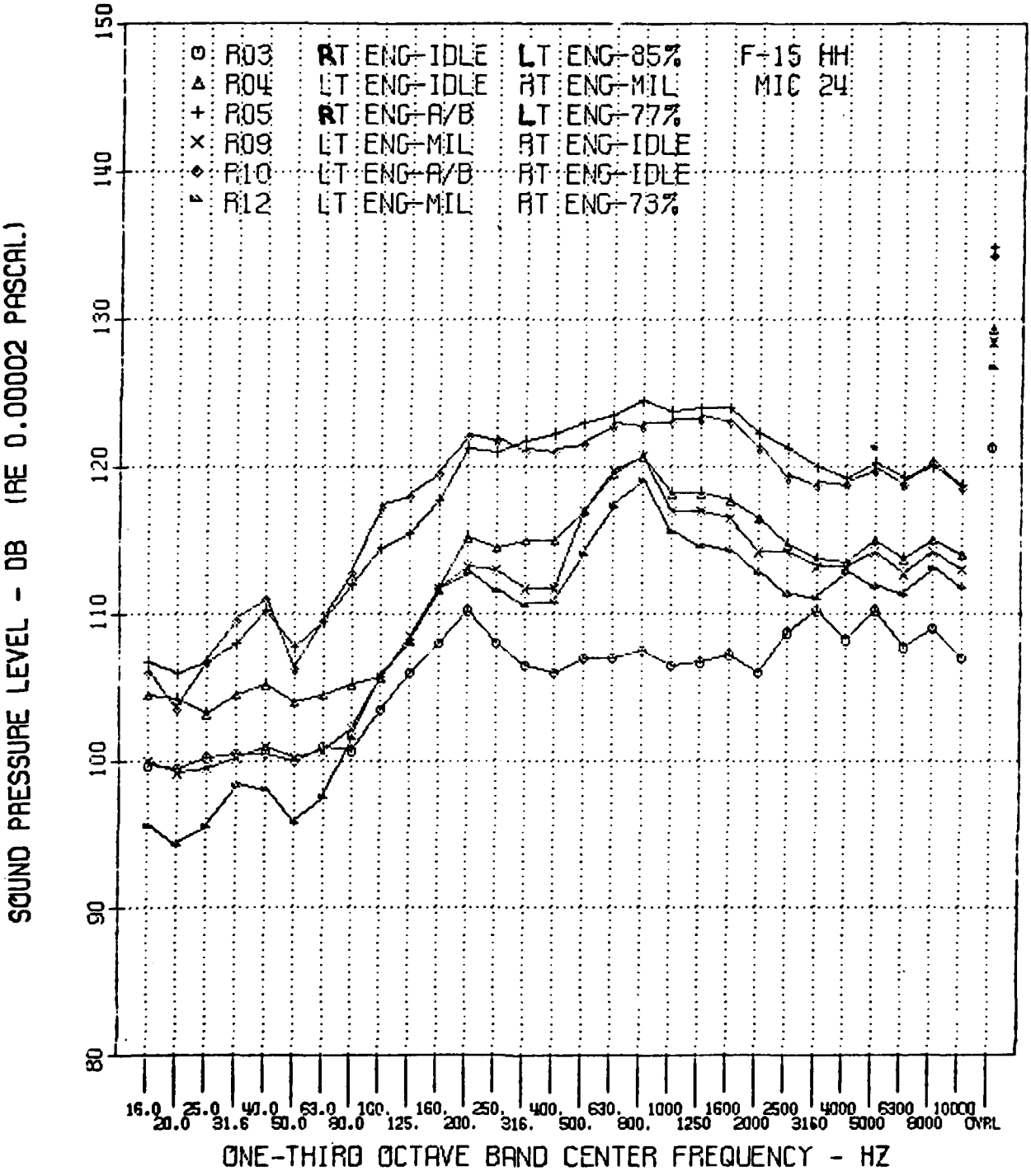

FIGURE B48 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 3, 4, 5, 9, 10, 12 - Microphone 24.

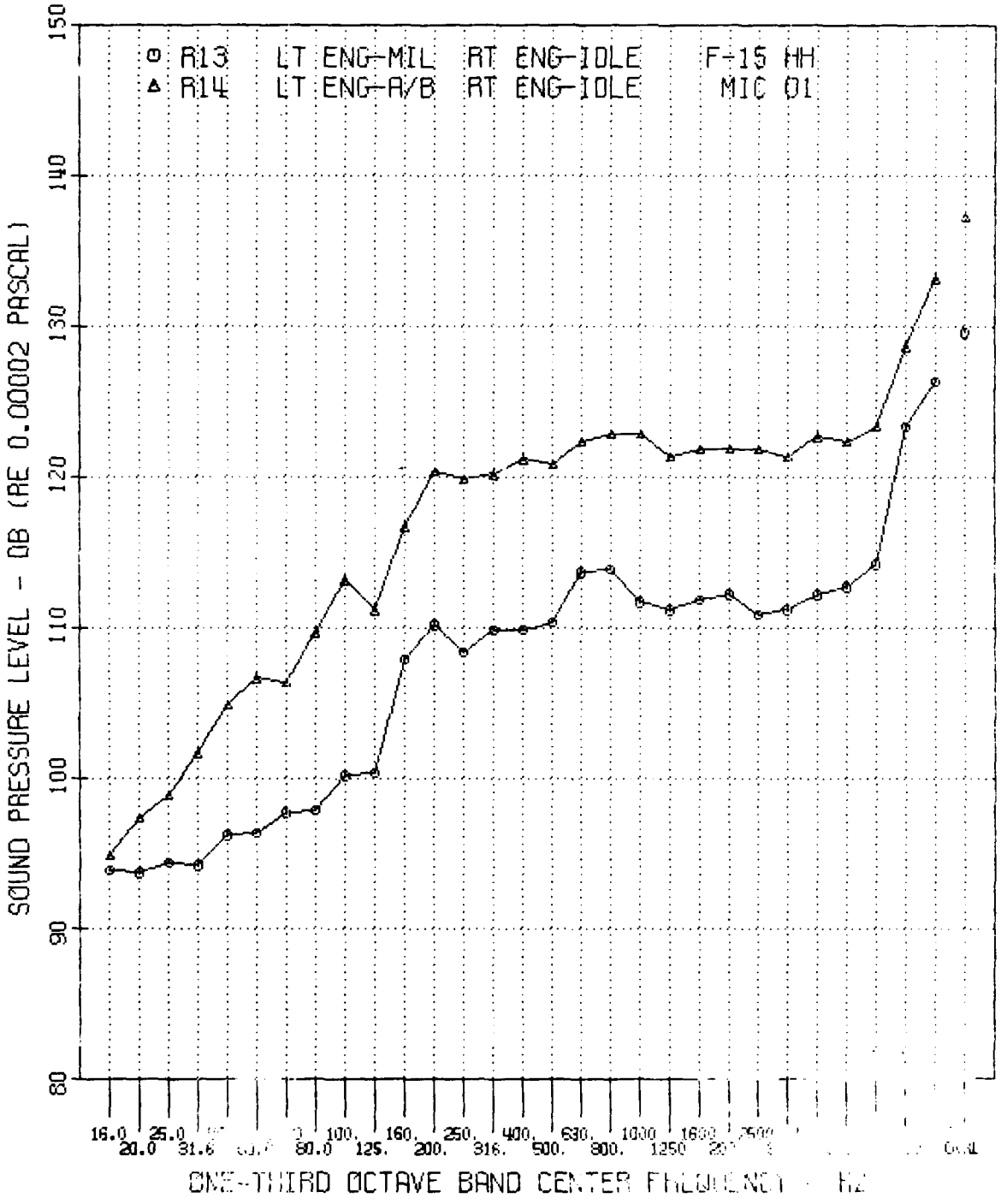

FIGURE B49 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 13, 14 - Microphone 1.

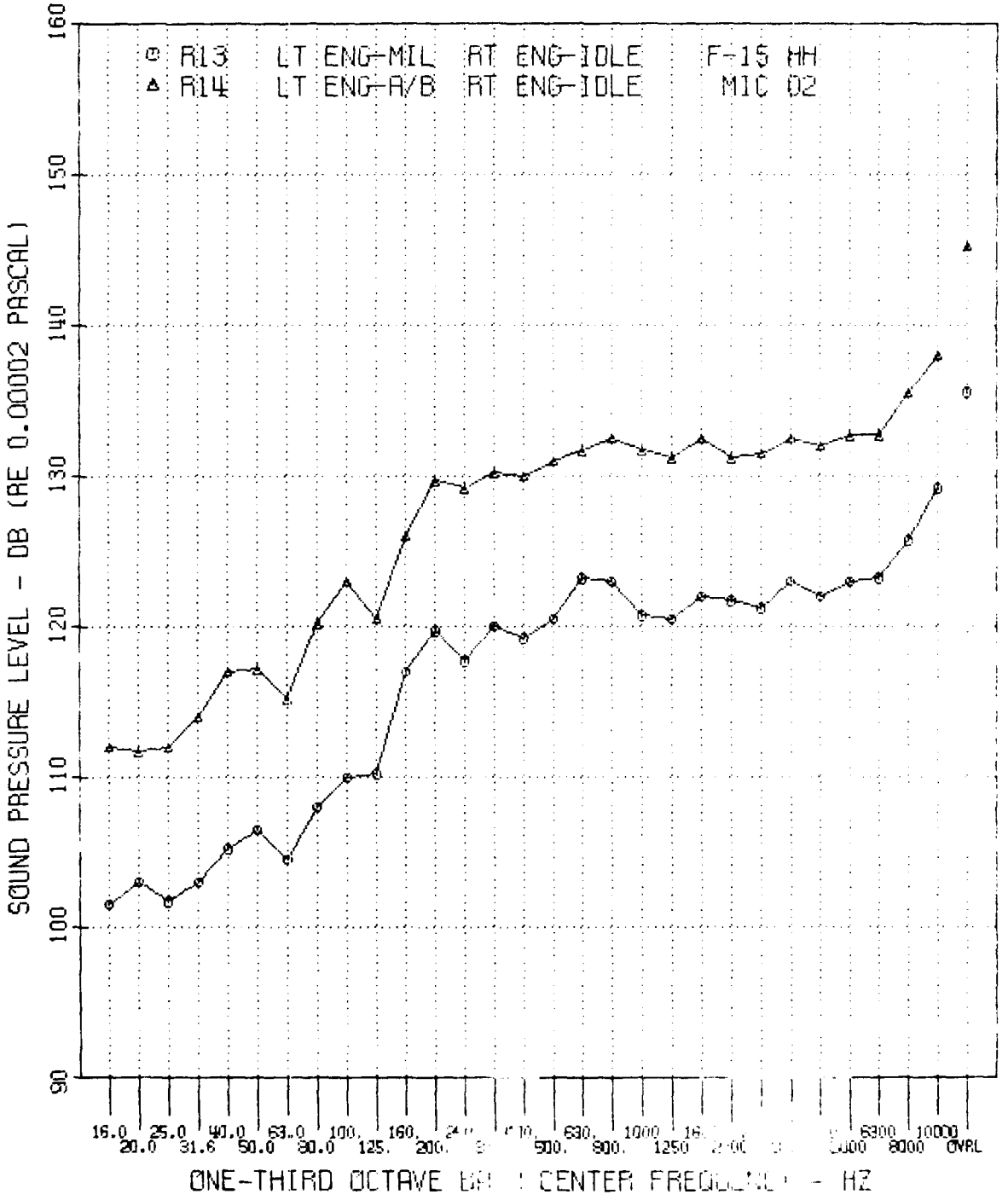

FIGURE B50 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 13, 14 - Microphone 2.

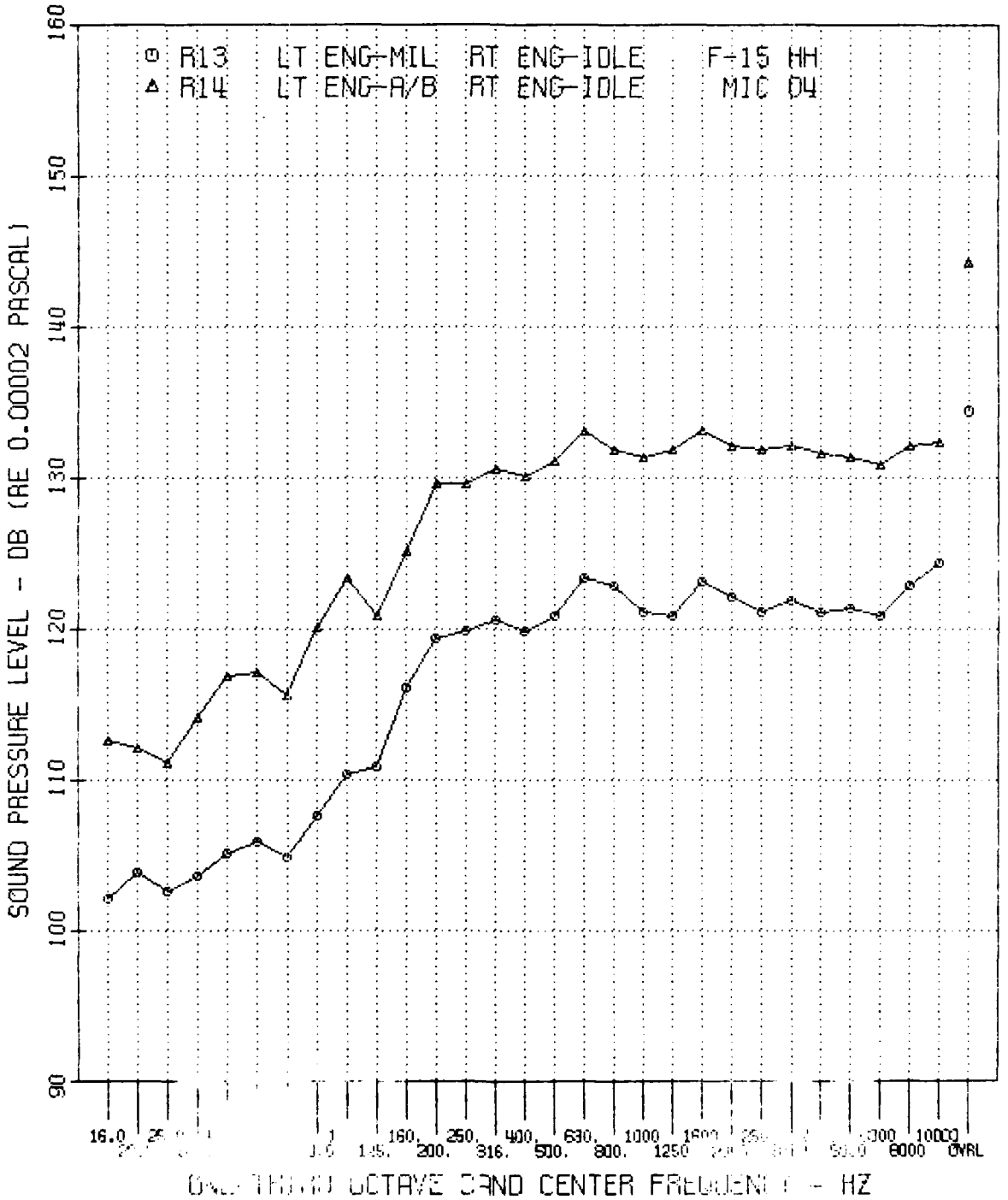

FIGURE B51 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 13, 14 - Microphone 4.

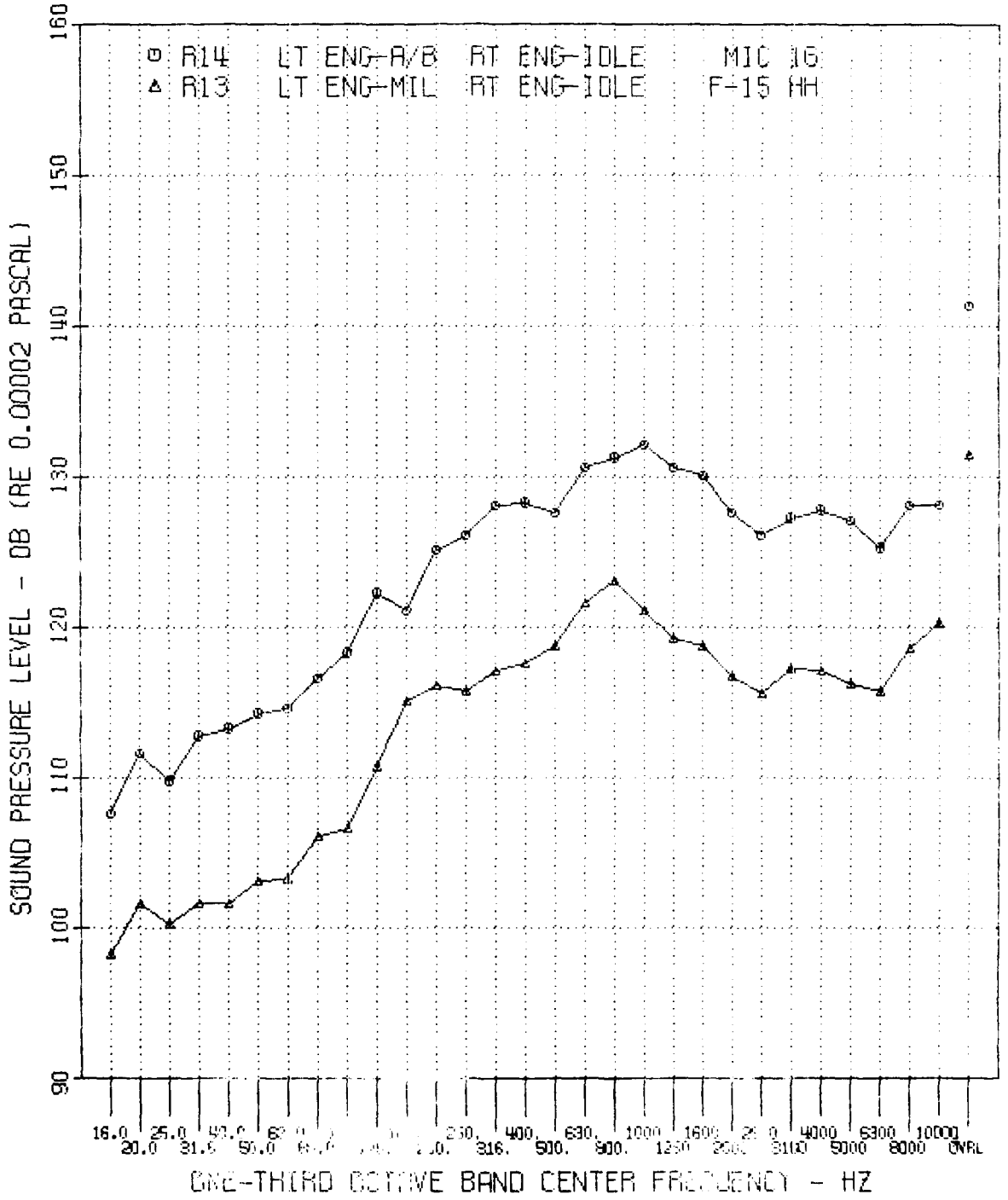

FIGURE B52 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 13, 14 - Microphone 16.

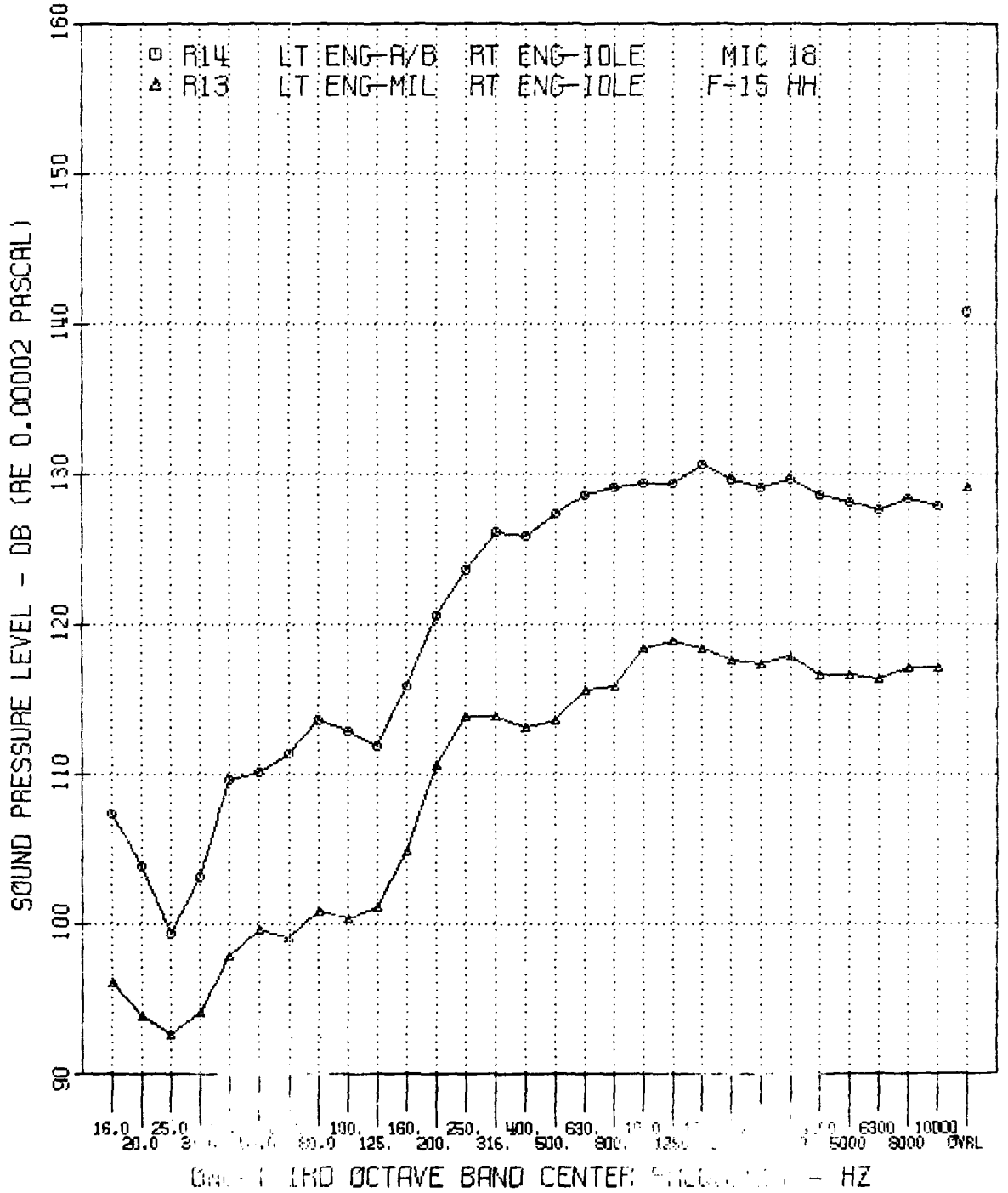

FIGURE B53 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 1 [illegible]4 - [illegible] rophone 18.

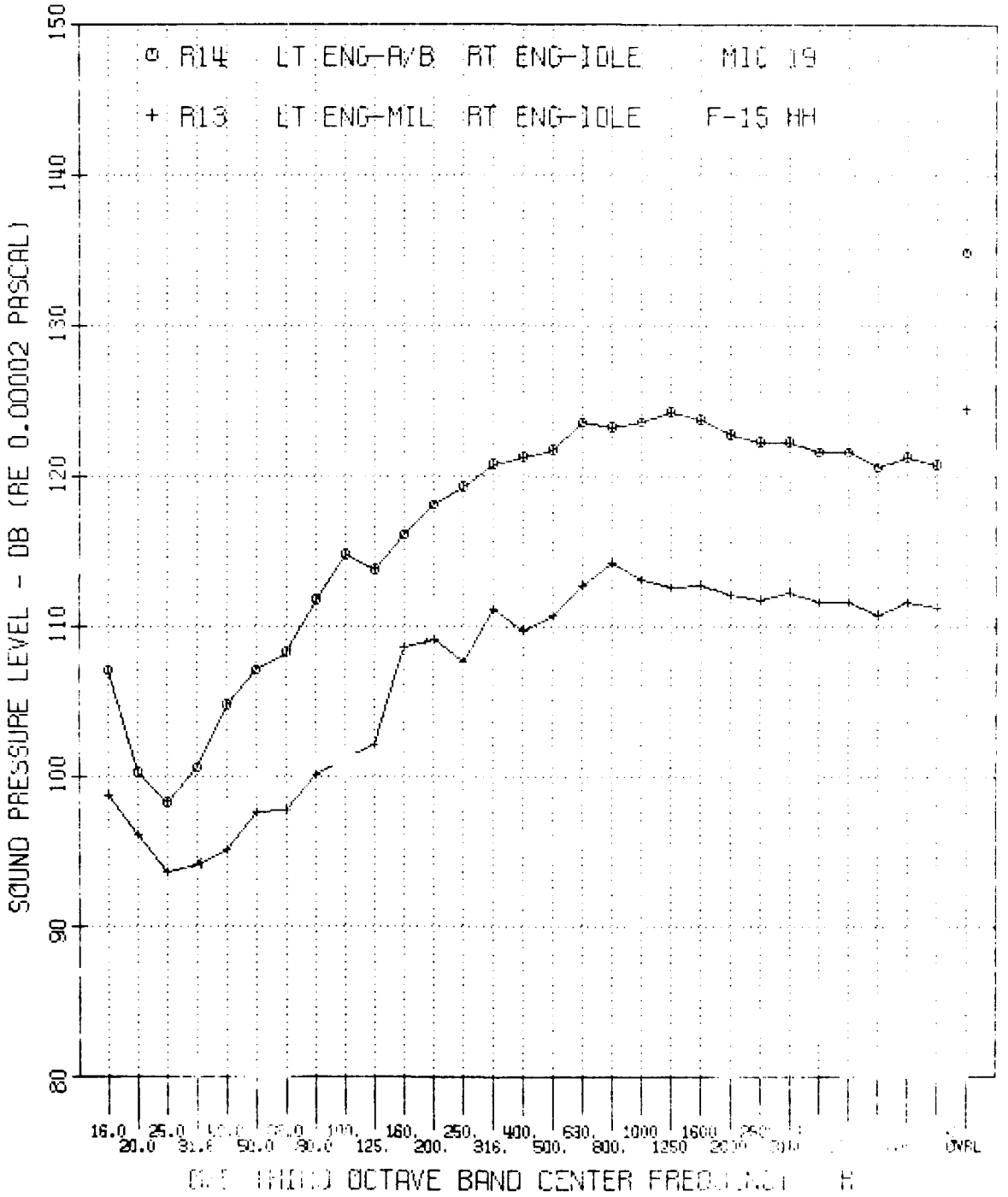

FIGURE B54 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 13, 14 - Microphone 19.

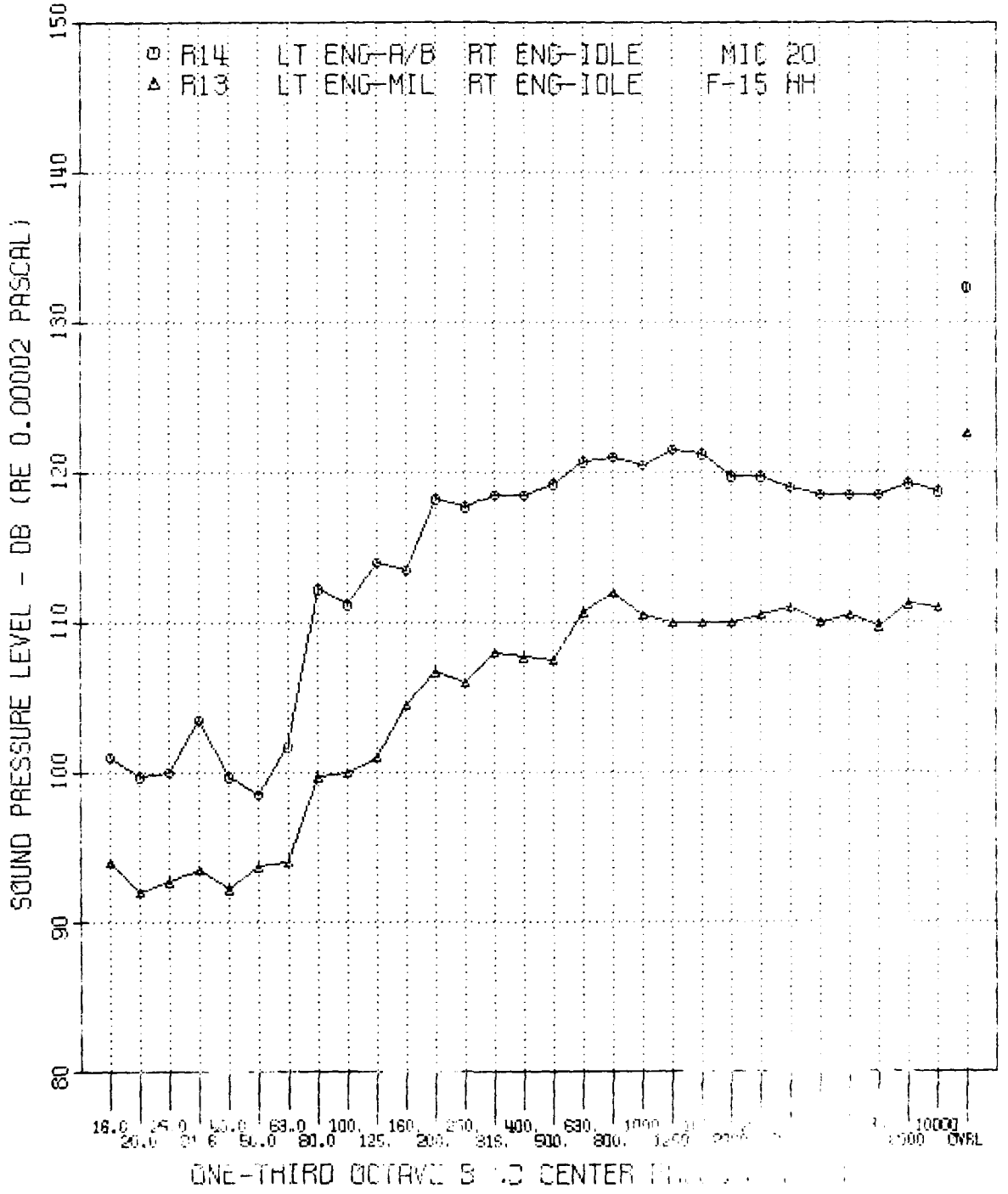

FIGURE B55 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 13, 14 - Microphone 20.

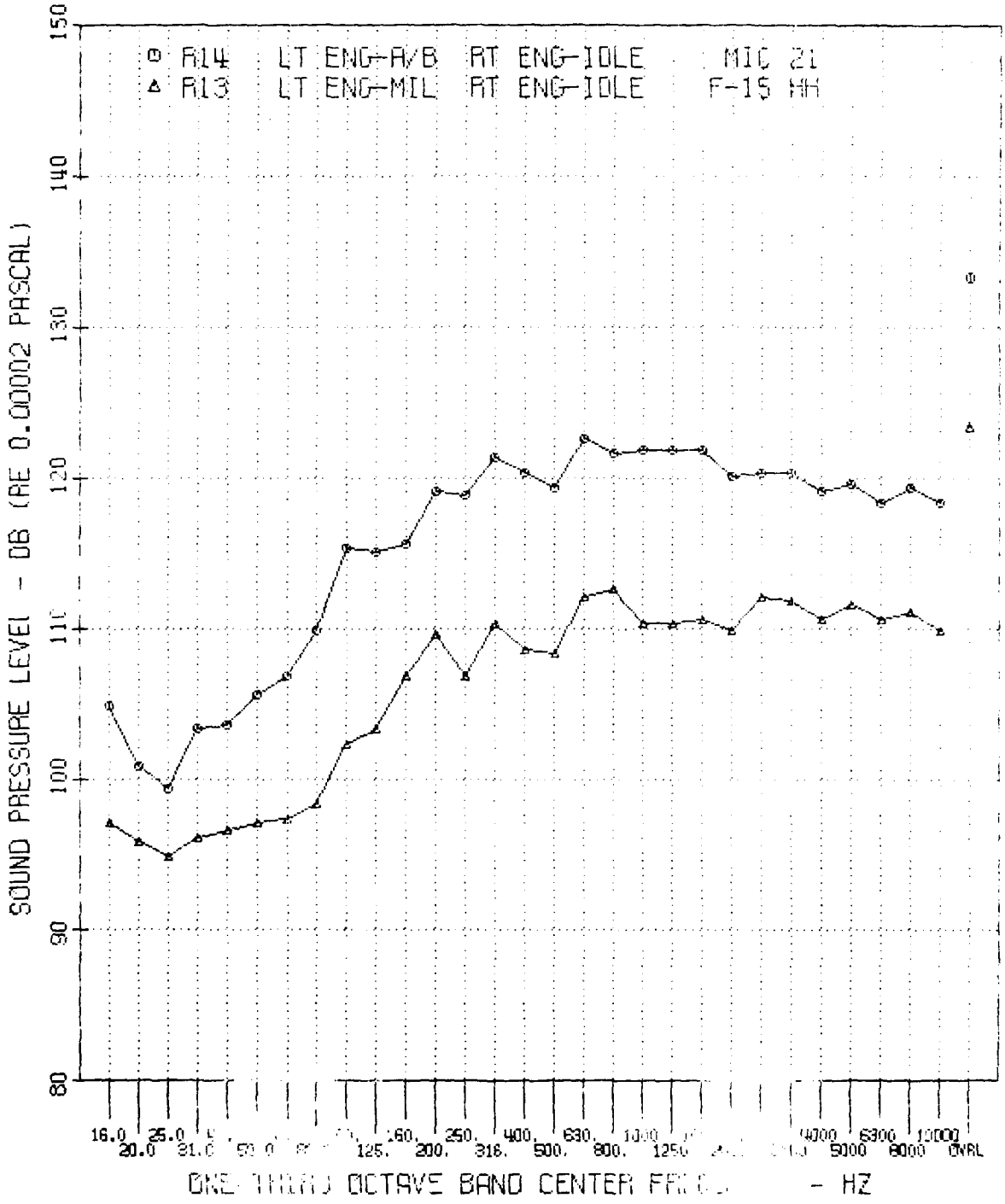

FIGURE B56 One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 13, 14 - Microphone 21.

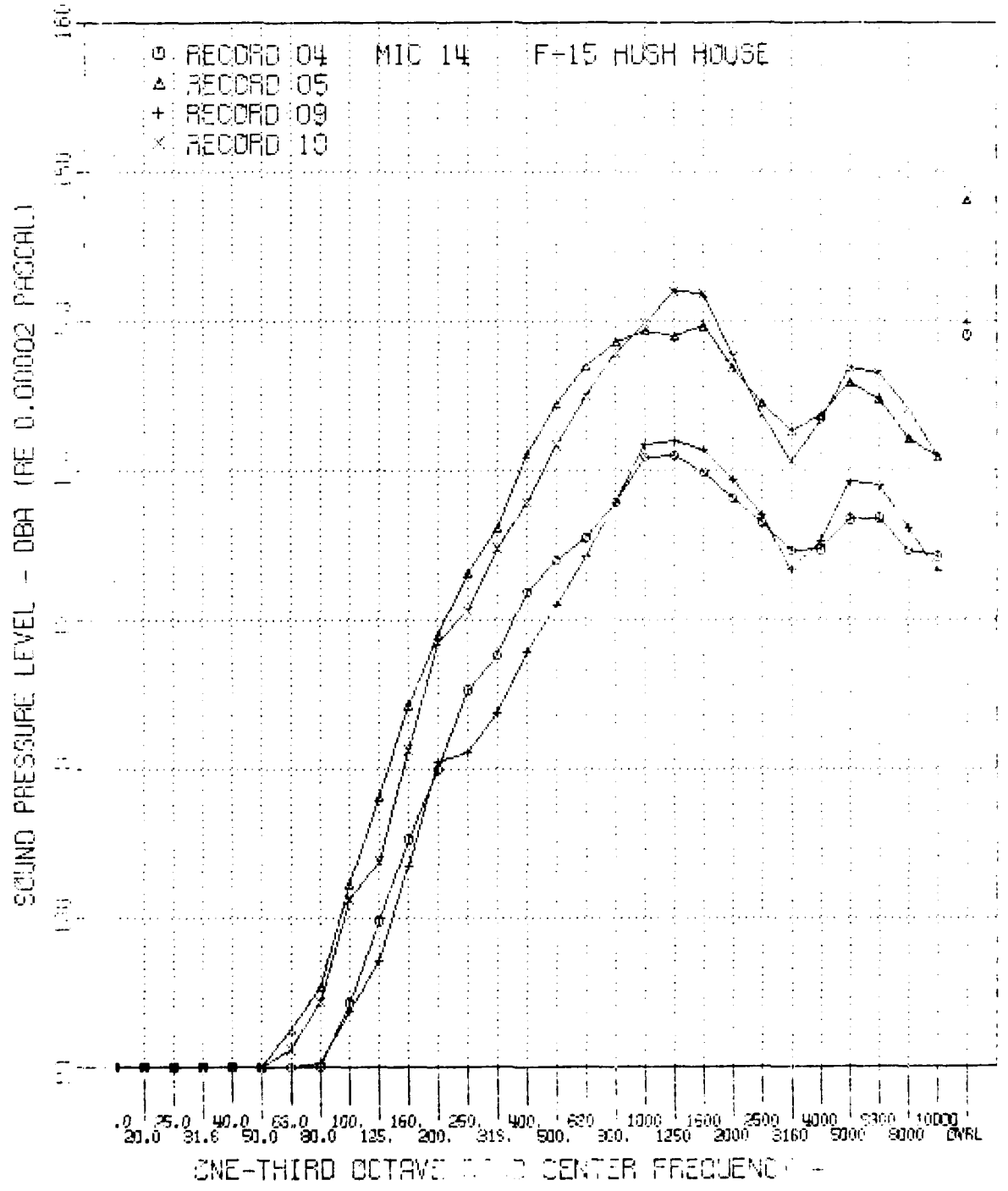

FIGURE B57 A-Weighted One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 14.

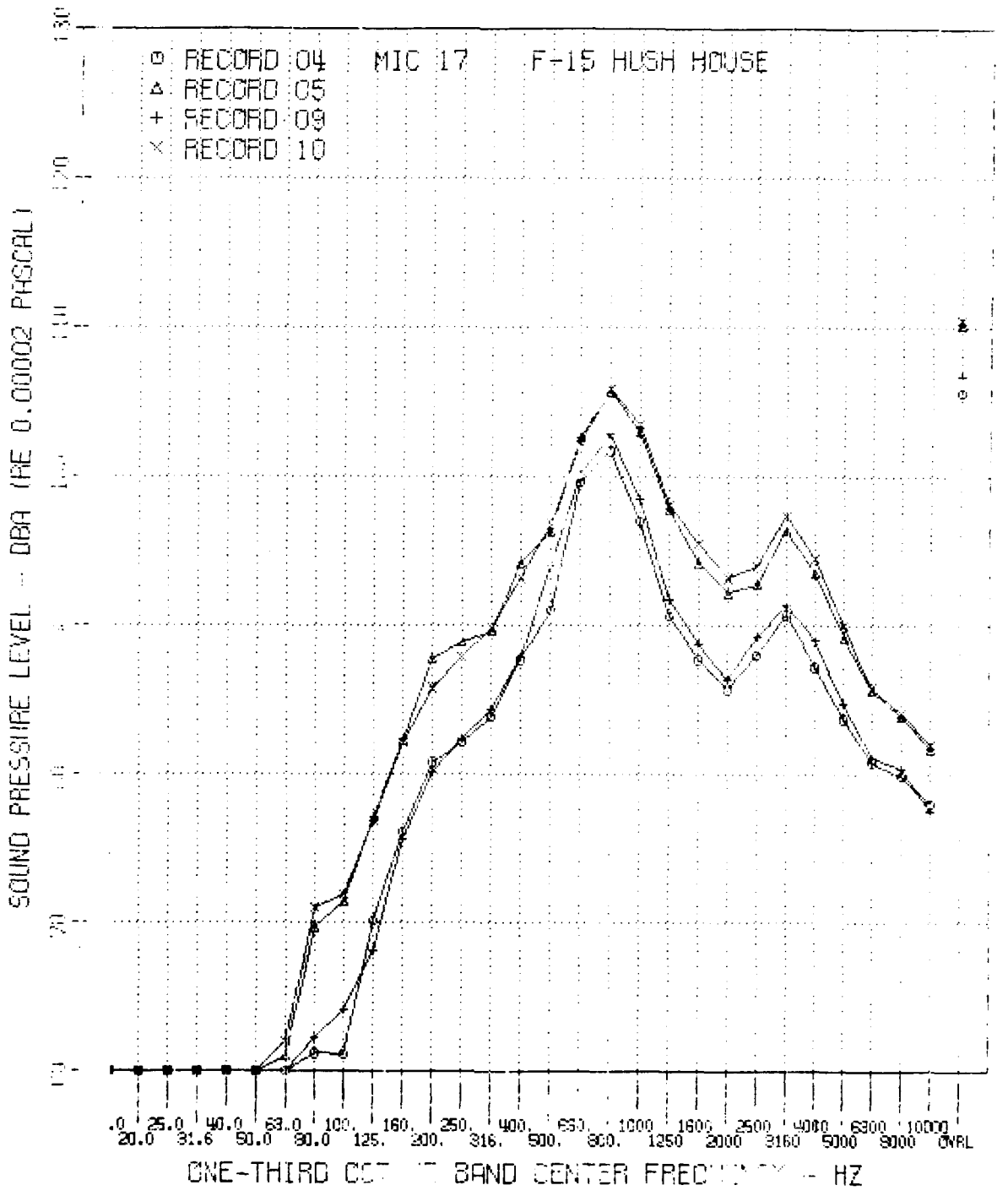

FIGURE B58 **A-Weighted One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 17.**

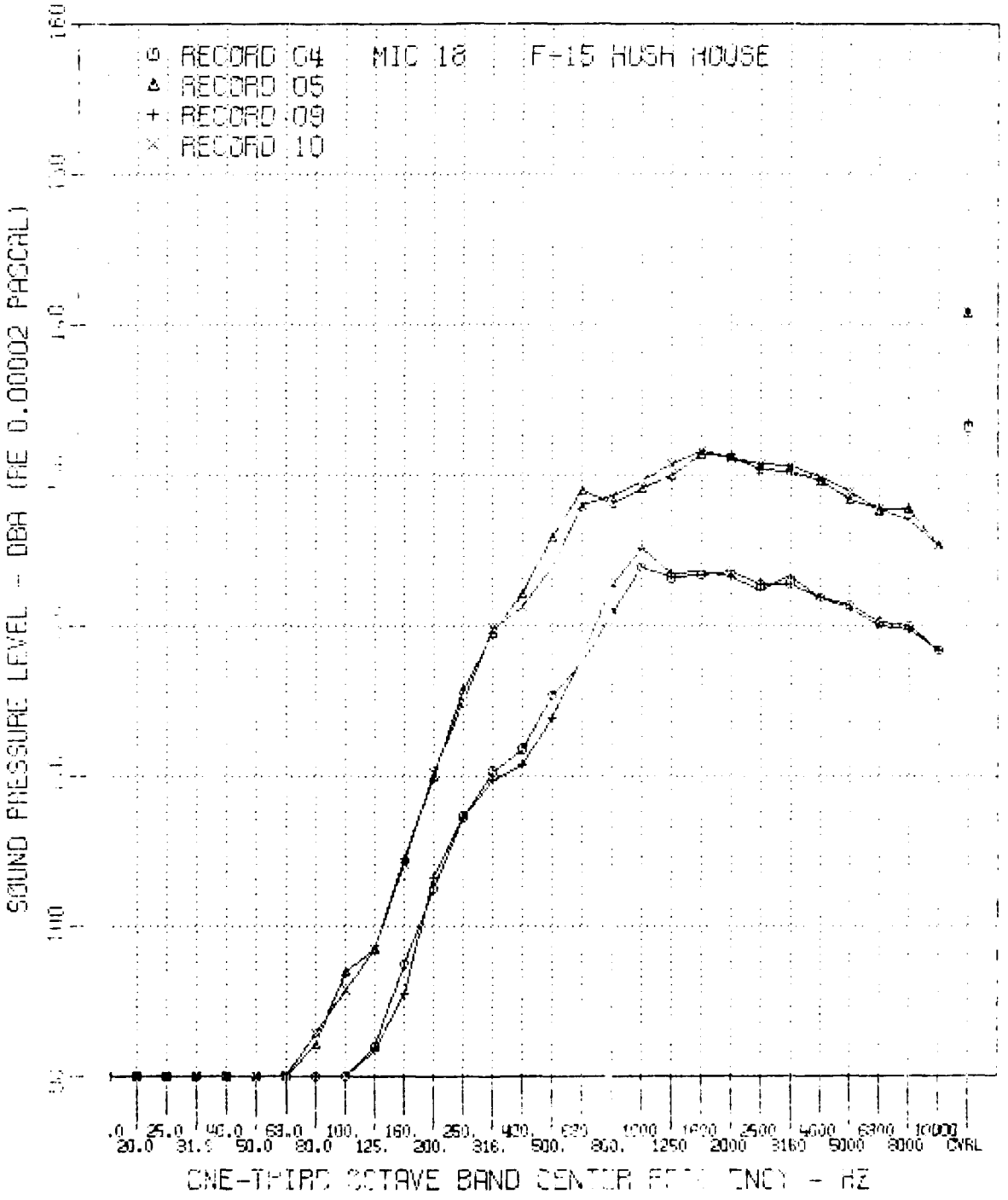

FIGURE B59 A-Weighted One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 18.

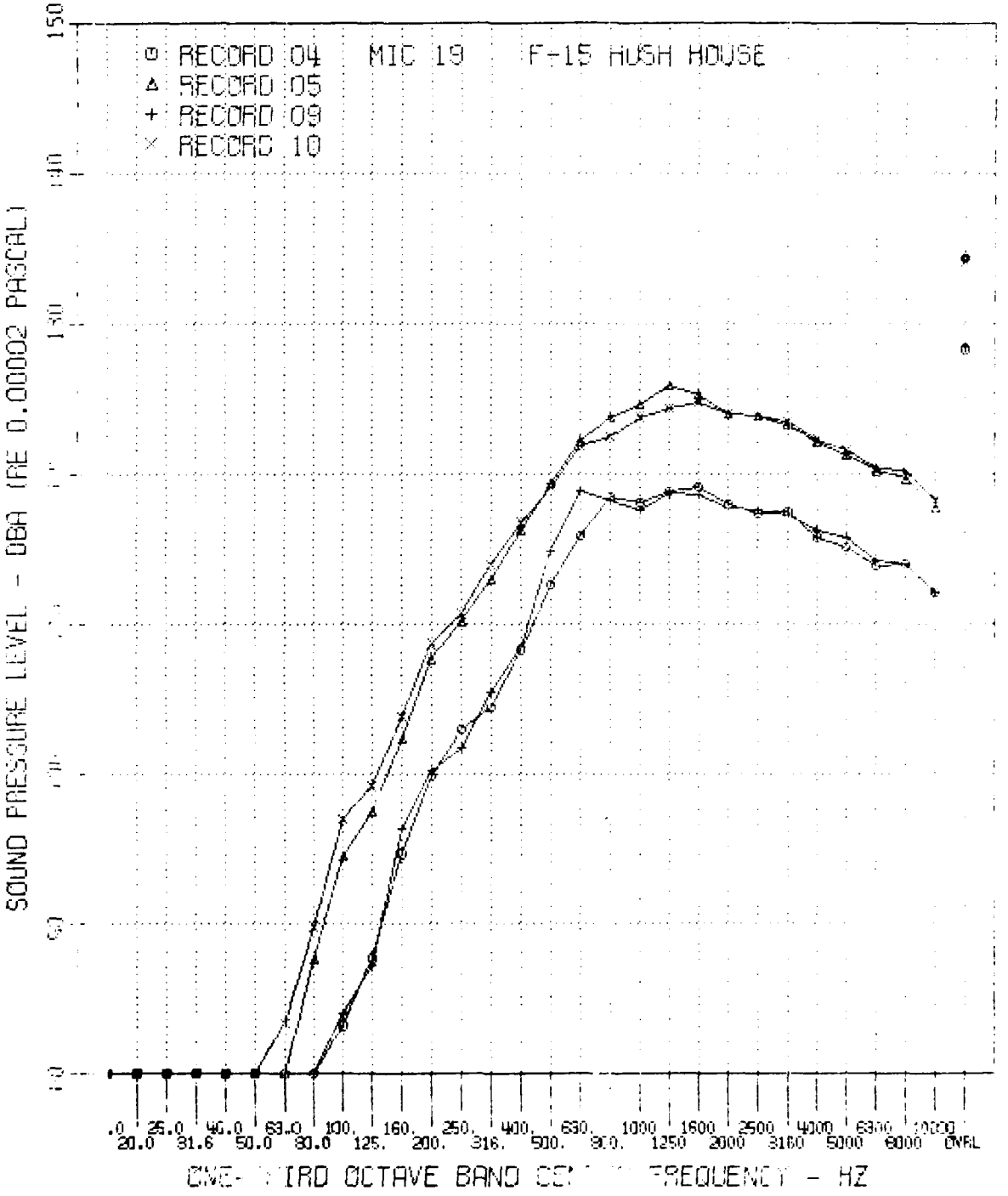

FIGURE B60 A-Weighted One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 19.

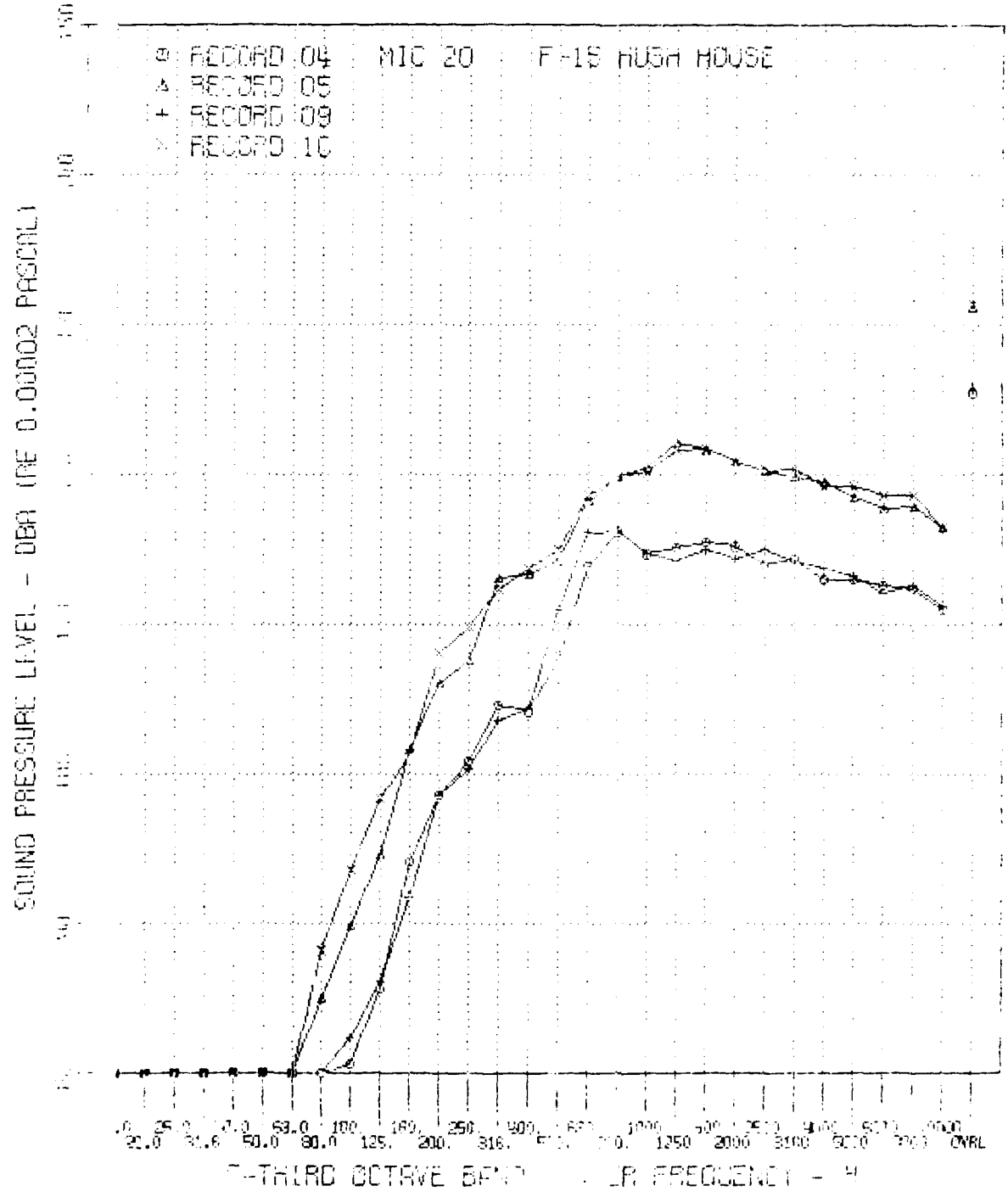

FIGURE B61 A-Weighted One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 20.

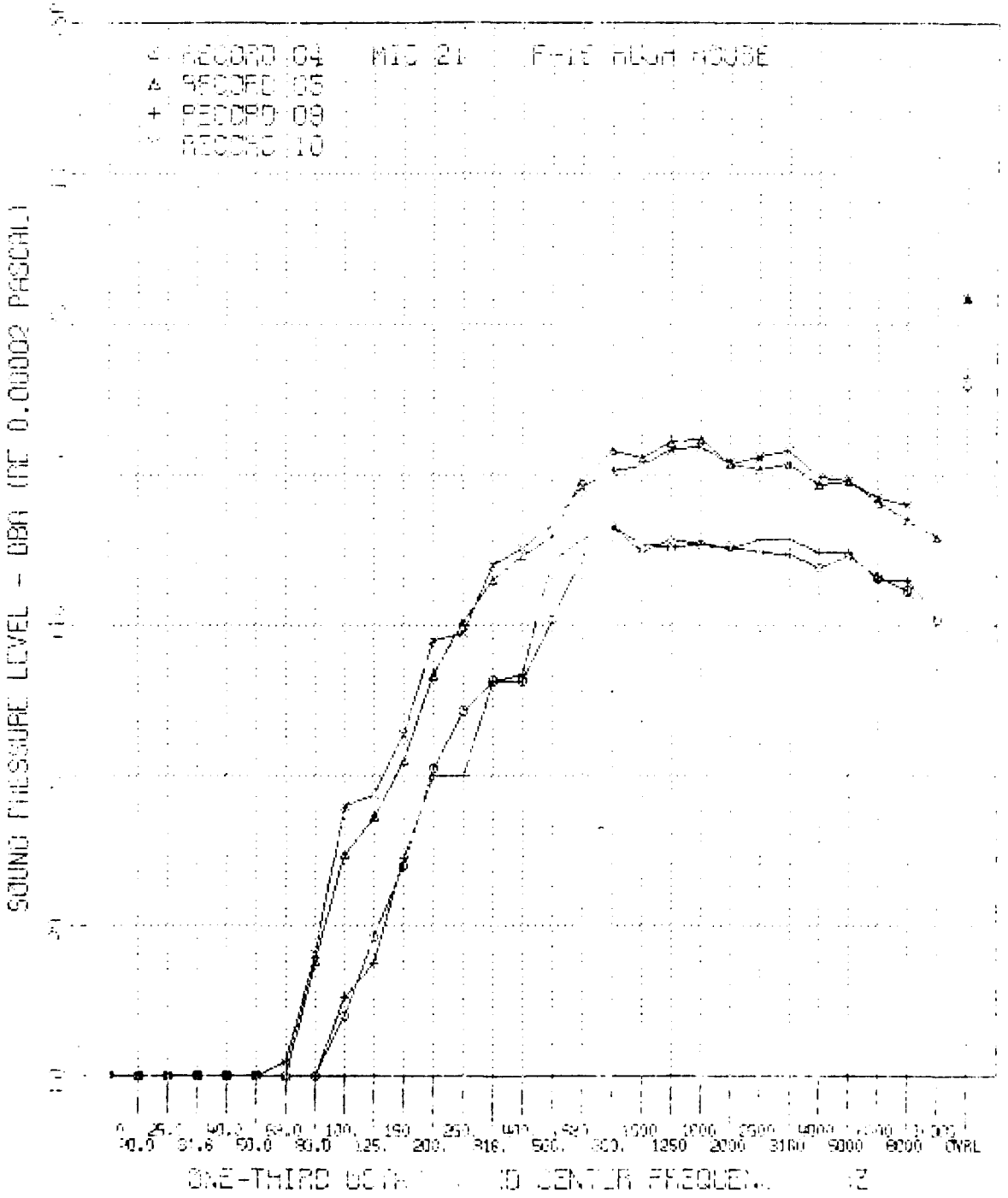

FIGURE B62 A-Weighted One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 21.

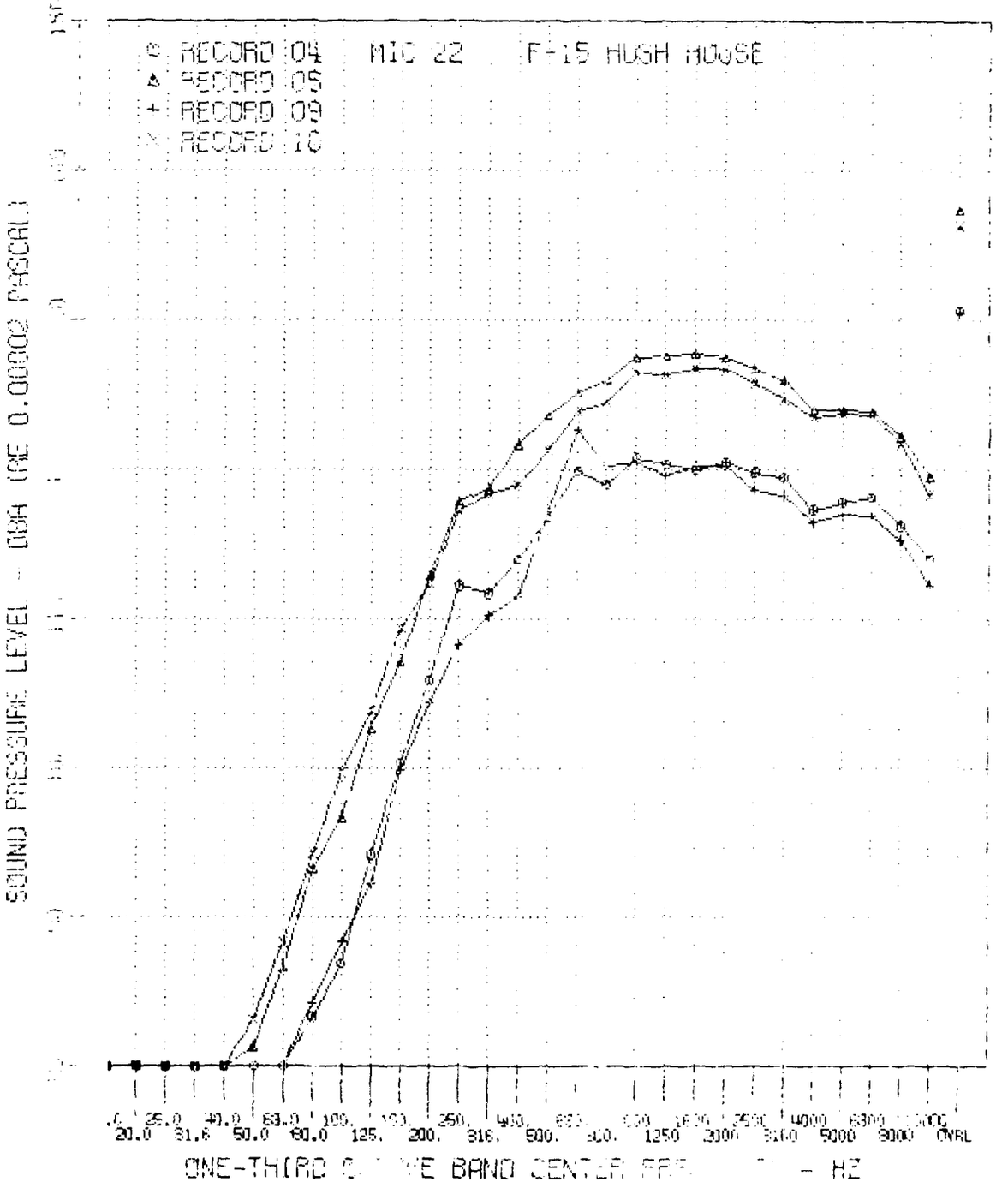

FIGURE B63 A-Weighted One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 22.

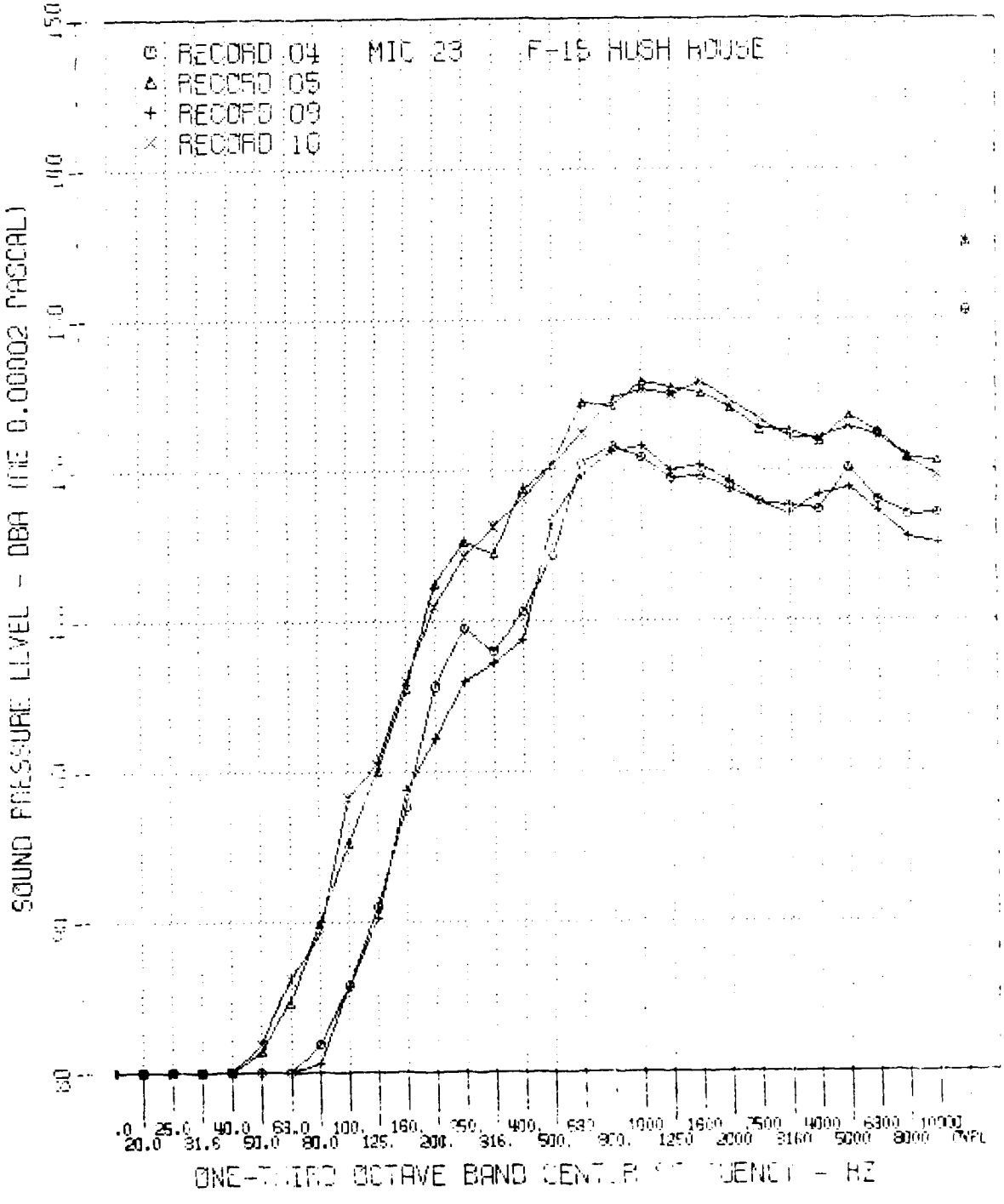

FIGURE B64 **A-Weighted One-Third Octave Band Spectra for F-15 Aircraft Installed in Hush House for Record Numbers 4, 5, 9, 10 - Microphone 23.**

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3. Data recorded with F-15 Aircraft Operating in an A/F32A-23 Noise Suppressor System Manufactured by Enelco

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